Steam Trap Monitoring

2022-NR-COV-PROC3-D **|** Nonresidential **|** June 2020 DRAFT CASE REPORT

Prepared by AESC, Inc., Energy Solutions

Please submit comments to info@title24stakeholders.com by July 17, 2020.

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Executive Summary

This is a draft report. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented in this draft report. When possible, provide supporting data and justifications in addition to comments. Suggested revisions will be considered when refining proposals and analyses. The Final CASE Report will be submitted to the California Energy Commission in September 2020.

In particular, comments on the following calculation input assumptions are desired:

1. ***The Statewide CASE Team is investigating the impacts of an integral strainer configuration. Depending upon the outcome of this analysis, we may recommend that strainers be installed in systems operating at 15 psig and above. Are there any reasons that the strainer requirements should not be applied to steam traps being served with steam at pressures between 15 psig and 30 psig? Are there any reasons that steam trap fault detection and diagnosis should not be applied to steam traps between 15 psig and 30 psig?***
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Introduction

The Codes and Standards Enhancement (CASE) Initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update the California Energy Efficiency Building Standards (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. Three California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas and Electric, and Southern California Edison – and two Publicly Owned Utilities – Los Angeles Department of Water and Power and Sacramento Municipal Utility District - (herein referred to as the Statewide CASE Team when including the CASE Author) sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposals presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy-efficient design practices and technologies.

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2022 Title 24 website for information about the rulemaking schedule and how to participate in the process: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.

The overall goal of this CASE Report is to present a code change proposal for steam trap monitoring. The report contains pertinent information supporting the code change. Industrial users are expected to continue consuming natural gas as a fuel source, and this measure targets the sector with significant natural gas savings and similarly significant decarbonization potential.

Measure Description

Background Information

Steam systems, most often located in industrial settings, are large consumers of natural gas. In the state of California, industrial natural gas consumption has been higher than any other end use for the past few years and is therefore a prime candidate to target for natural gas efficiency measures (U.S. Energy Information Administration 2020). Steam traps are a mechanical valve that separates live steam from condensate and non-condensables (e.g., air). Most steam traps have moving parts that degrade over time and eventually fail. Solid contaminants in the steam system can also clog steam traps and result in failure in a partially open condition. When steam traps fail in the open position or leak, steam is vented into the atmosphere through the condensate return system resulting in the loss of significant amounts of energy and treated water.

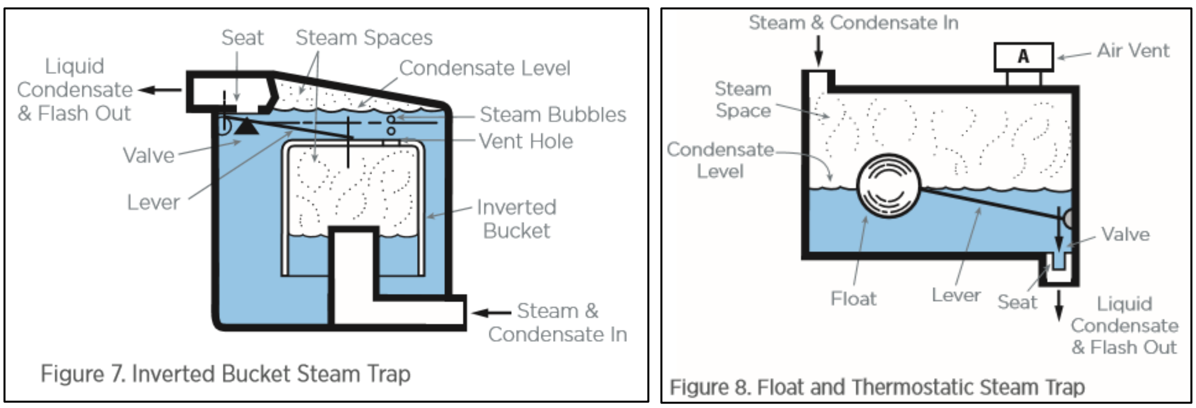

Figure 1: Two common types of steam traps, inverted bucket steam trap (Left) and float and thermostatic steam trap (Right).

Source: (Energy n.d.)

Automatic steam trap monitoring through fault detection diagnostics (FDD) provides a method that reports any failure instantly and eliminates the labor required to manually check the steam trap(s). Steam trap monitoring systems are available from multiple sources including the manufacturers of steam traps and manufacturers of industrial and building controls.

Automatic steam trap monitoring systems use steam trap fault detection sensors which monitor the conditions of the traps and upon detection of a fault, send a signal to the central steam trap monitoring system. The central steam trap monitoring system then transmits an alarm to the facility operator, identifying which steam trap has registered the fault. Data collected can include temperature, ultrasonic signals, and other information that makes it possible to diagnose steam trap malfunction. Wired or wireless systems can be used to remotely transmit signals that report the trap condition. Signals are received by a central software application that measures, monitors, and manages this information. This enables plant operators to capture real-time steam trap operation data and quickly correct malfunctions.

Strainers in steam distribution system are mechanical in-line pipe fittings housing a metal screen which filter and separate solid matter allowing steam and condensate to pass through. Blow-off, or blowdown, valves in steam distribution systems are mechanical valves periodically vented to the atmosphere, discharging all solids which had been separated and captured by the strainer. Installing strainers and blow-off valves upstream of steam traps increases steam trap life and renders it less likely that the steam trap would experience a failure. This code proposal would codify steam system best practices for installation of strainers and blow-off valves in addition to automatic steam strap monitoring, see Figure 2.

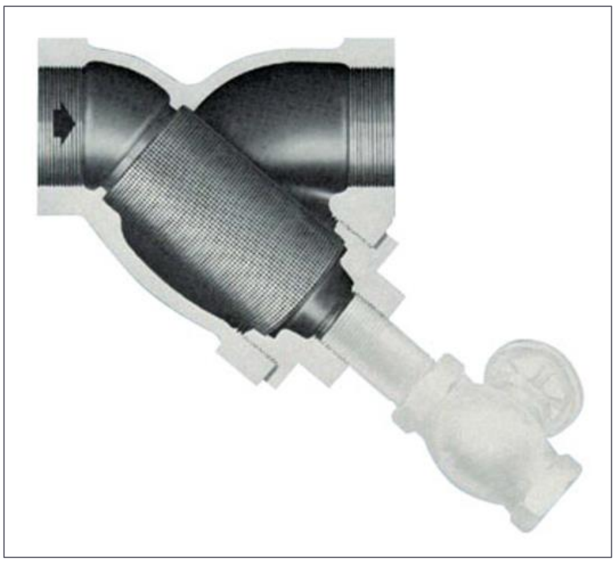

Figure 2: Strainer with blow-off valve to the bottom(-right).

Source: (Sales n.d.)

The proposed code change to Section 120.6 includes two mandatory compliance requirements, 1) the installation of steam trap FDD and 2) steam trap strainer installation (includes strainer and blow-off valve installation upstream of a steam trap). This measure would apply to all new construction, all additions and all steam trap alterations that meet the proposed code requirements. The proposed code change impacts the largest natural gas end uses in California: all covered process steam systems, including oil and gas producers, food processors, healthcare facilities, pharmaceuticals and manufacturing operations that use steam traps with connected steam line operating pressures greater than 30 pounds per square inch gauge (psig) and with total combined connected boiler input capacity rating greater than or equal 2,000,000 Btu/hr (2.0 MMBtu/hr). The proposed code does not impact space heating or domestic hot water heating applications. The total combined connected boiler input capacity rating exception is intended to trigger the measure code for sites that would replace a significant number of steam traps and thereby generate a significant savings potential due to the energy-intensive usage of process loads and large size capacity. At the same time, the measure would allow control point cost to stay down and smaller users to operate using manual assessment methods.

Title 24, Part 6 does not currently regulate the installation of steam traps or require the installation of a strainer with a blow-off valve. The proposed code change represents an addition to Title 24, Part 6 and supplemental documentation where none previously existed.

The proposed measure aims to reduce the overall time a steam trap is left in a failed position, specifically an open (blow-through) position. The primary concern with steam trap failure in an open position is that the failure can go unnoticed for extended periods of time and the associated equipment would continue to operate while wasting energy due to the trap failure. Failure in the closed position wastes minimal energy but impacts overall system performance.

Steam trap effective useful life, quantified by the duration between failures, is improved by using a strainer and blow-off valve upstream of the steam trap. Strainers, and blow-off valves, act to reduce the amount of debris and other contaminants that enter a steam trap, which degrade the device and ultimately lead to otherwise premature failure of the steam trap. Installation of strainers and blow-off valves for all new construction, all additions and all steam trap alterations would increase the duration between steam trap failures.

Additional benefits of the proposed measure may include improved system reliability, reduced overall maintenance, and increased process run time.

Proposed Code Change

The proposed code addition is a mandatory requirement to Section 120.6, Mandatory Requirements for Covered Processes. All new construction, all additions and all steam trap alterations, with connected steam line operating pressure equal to or greater than 30 psig would be subject to the installation of steam trap fault detection and diagnostics per proposed changes to Section 120.6(h)1. All new construction, all additions and all steam trap alterations with connected steam line operating pressure equal to or greater than 30 psig shall have an integral strainer and blow-off valve or the steam trap shall be installed downstream within three feet from the exit of the strainer fitting, per Section 120.6(h)2. “Steam trap alterations” is defined as the replacement of a steam trap. Section 120.6(h)1 and 120.6(h)2 contain a code exception for systems with total combined connected boiler input capacity rating less than 2,000,000 Btu/hr (2.0 MMBtu/hr).

Scope of Code Change Proposal

Table 1 summarizes the scope of the proposed changes and which sections of Standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manual, and compliance documents that would be modified as a result of the proposed change(s).

Table 1: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Section(s) of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Would Compliance Software Be Modified	Modified Compliance Document(s)
Steam Trap Monitoring	Mandatory	120.6- Mandatory Requirements for Covered Processes	Nonresidential Appendix 7	No	A new acceptance test form, NRCA-PRC-17-F, would be added to certify measure meets acceptance requirements specified in NA 7. The following forms would be modified: • NRCC-PRC-E • NRCI-PRC-01-E

Market Analysis and Regulatory Assessment

Steam is used for a variety of industrial processes, space heating and power generation applications due to its high heating value and potential energy properties. In industrial process applications, steam systems consist of four main subsystem components including: steam supply/generation source, steam distribution, end use equipment/processes and condensate return systems, see Figure 3. When heat recovery is not available for creating steam, a steam boiler would be the supply/generation source and is an energy intensive process. Steam traps are mechanical devices which separate live steam from condensate and non-condensables (e.g. air), see Figure 1. Over time steam trap components can degrade or get blocked, leading to the potential for live steam to blow-through the steam trap, resulting in wasted energy. Automatic steam trap monitoring can support a robust maintenance program by providing early identification of failed steam straps.

Automatic steam trap monitoring systems are offered by a wide variety of manufacturers. The technology is well established, and its use is documented in many process steam system studies. Wide market adoption has been limited to date. Manufacturer, distributor, and vendor interviews have indicated that steam traps, steam trap automatic monitoring components, strainers, and blow-off valves all have different expected useful lives. Steam traps in the absence of strainer and blow-off valve assemblies were estimated to have an average life expectancy of four years based on stakeholder outreach. Steam trap automatic monitoring system were estimated to have an average life expectancy of ten years based on stakeholder outreach. Therefore, a measure life evaluation with the lowest common denominator of 15-years is suitable, rather than the alternative 30-year evaluation period. Steam traps with strainer and blow-off valve assemblies, strainers and blow-off valves were estimated to have an average of seven and a half years life expectancy. Therefore, the steam trap strainer installation measure utilizes the 15-year measure life evaluation, too. Over the 15-year period of analysis the various replacement intervals are evaluated with costs discounted using a three percent real discount rate. Savings would persist in the presence of established end user facility maintenance practices.

This proposal is cost effective over the period of analysis. Overall, California end users subject to the proposed code measure would save more money on energy than they would spend to implement the measure over the 15-year measure life.

The proposed changes to Title 24, Part 6 would impact various market actors in the compliance process and have a net increase in the cost of enforcement. When developing this measure proposal, the Statewide CASE Team interviewed market actors and subject matter experts from all stages of the compliance process. The goal is to simplify, streamline, and minimize incurred burden on all market actors for compliance and enforcement yet deliver the energy savings impact. Market actors impacted by the compliance process would include Designers, Plans Examiners, Installers, Facility Managers, and Field Technicians.

Title 24, Part 6 does not currently include relevant existing requirements for steam distribution systems, steam traps, or steam trap fault detection and diagnostics systems. There are no relevant requirements in other parts of Title 24, Part 6 or local, state, or federal laws or other industry standards.

Cost Effectiveness

The proposed code change was found to be cost effective for all climate zones where it is proposed to be required. The benefit-to-cost (B/C) ratio compares the benefits or cost savings to the costs over the 15-year period of analysis. Proposed code changes that have a B/C ratio of 1.0 or greater are cost effective. The larger the B/C ratio, the faster the measure pays for itself from energy cost savings. The B/C ratio for steam trap monitoring is 1.19, and for steam trap strainer installation is 1.13. See Section 5 for the methodology, assumptions, and results of the cost-effectiveness analysis.

Statewide Energy Impacts: Energy, Water, and Greenhouse Gas (GHG) Emissions Impacts

Table 2 presents the estimated energy and demand impacts of the proposed code change that would be realized statewide during the first 12 months that the 2022 Title 24, Part 6 requirements are in effect. First-year statewide energy impacts are represented by the following metrics: electricity savings in gigawatt-hours per year (GWh/yr), peak electrical demand reduction in megawatts (MW), natural gas savings in million therms per year (million therms/yr), and time dependent valuation (TDV) energy savings in kilo British thermal units per year (TDV kBtu/yr).

The Statewide CASE Team strives to present a cost-effective path towards carbon neutrality. While electricity savings are presented in GWh and natural gas savings in million therms, it is important to note that one million therms represent 29 times the carbon savings associated with one GWh.

See Section 6 for more details on the first-year statewide impacts calculated by the Statewide CASE Team. Section 4 contains details on the per-unit energy savings calculated by the Statewide CASE Team.

Table 2: First-Year Statewide Energy and Impacts

Measure	Electricity Savings (GWh/yr)	Peak Electrical Demand Reduction (MW)	Natural Gas Savings (million therms/yr)	TDV Energy Savings (TDV kBtu/yr)
Automatic Steam Trap Monitoring (Total)	**0.026**	**N/A**	**1.280**	**325,747,000**
New Construction and Additions	0.001	N/A	0.061	15,514,000
Alterations (Steam Trap Replacements)	0.025	N/A	1.219	310,233,000
Steam Trap Strainer Installation (Total)	**0.005**	**N/A**	**0.248**	**63,081,000**
New Construction and Additions	0.000	N/A	0.004	1,034,000
Alterations	0.005	N/A	0.244	62,047,000

The energy analysis assumes that in the absence of monitoring, it takes six months to identify a failed steam trap and begin the repair process based on stakeholder feedback. This is because in the absence of automatic monitoring, on average a facility conducts an inspection of their traps annually and failed open/partial-open traps continue to operate, but waste energy during this time. For the steam trap strainer installation analysis, the strainer was assumed to improve the life of a steam trap by fifty percent, from four years to six years. These assumptions are discussed in more detail in Section 4.

Table 3 presents the estimated avoided GHG emissions associated with the proposed code change for the first year the standards are in effect. Avoided GHG emissions are measured in metric tons of carbon dioxide equivalent (metric tons CO2e). Assumptions used in developing the GHG savings are provided in Section 6.2 and Appendix C of this report. The monetary value of avoided GHG emissions is included in TDV cost factors and is thus included in the cost-effectiveness analysis.

Table 3: First-Year Statewide GHG Emissions Impacts

Measure	Avoided GHG Emissions (Metric Tons CO2e/yr)	Monetary Value of Avoided GHG Emissions (2023)
Automatic Steam Trap Monitoring	6,988	$279,518
Steam Trap Strainer Installation	1,353	$54,129
Total	**8,341**	**$333,647**

Water and Water Quality Impacts

Water savings that the proposed code changes would have during the first year they are in effect are presented in Table 4 along with the associated embedded electricity savings. See Table 33 in Section 6.3 of this report to see water quality impacts and the methodology used to derive water savings and water quality impacts. The methodology used to calculate embedded electricity in water is presented in Appendix B.

Table 4: First-Year Water and Embedded Electricity Impacts

	On-Site Indoor Water Savings (gallons/yr)	On-Site Outdoor Water Savings (gallons/yr)	Embedded Electricity Savings (kWh/yr)
Per Automatic Steam Trap Monitoring Impacts	N/A	867	3.09
Per Strainer Impacts	N/A	289	1.03
First-Year	N/A	8,765,000	31,000

Statewide Impacts			

Compliance and Enforcement

Overview of Compliance Process

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

- Steam system component manufacturers and installers would need to ensure the systems offered or installed are compliant with the code change.
- Steam system designers, installers, and facility operators would need to ensure that systems designed and proposed are compliant with the code change. Supplemental information to demonstrate compliance would also need to be gathered and supplied.
- Modifications would be needed to the forms NRCC-PRC-E Certificate of Compliance and NRCI-PRC-01-E Certificate of Installation to incorporate the new requirements.
- New Certificate of Compliance and Certificate of Acceptance or Certificate of Installation forms would need to be created, completed, and reviewed by varying market actors to reflect the new requirements.
- Plans examiners would have additional information within the Certificate of Compliance document that would need to be verified to ensure system designs comply with code change.
- New Certificate of Acceptance form NRCA-PRC-17-F would need to be filled out by the Field Technician.
- Building inspectors would have to verify the additional compliance document and code requirements to ensure steam trap fault detection and diagnostics systems and strainer assemblies comply with code requirements. These would include the modified NRCC, modified NRCI, and new NRCA forms listed above.
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Field Verification and Acceptance Testing

The proposed code addition includes a field verification construction and acceptance test requirement, to be completed by the Field Technician. Please see Section 2.5 for a detailed compliance path description.

1. Introduction

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The overall goal of this CASE Report is to present a code change proposal for steam trap fault detection and diagnostics (FDD) and steam trap quality installation. The report contains pertinent information supporting the code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with a number of industry stakeholders including building officials, FDD system manufacturers, steam system service providers, energy consultants, utility incentive program managers, Title 24 energy analysts, and others involved in the code compliance process. The proposal incorporates feedback received during a public stakeholder workshop that the Statewide CASE Team held on November 7, 2019 (Statewide CASE Team 2019). Additionally, the

Statewide CASE Team held numerous calls with individual subject matter experts from various stakeholder entities to discuss the proposal and gather relevant input.

The following is a brief summary of the contents of this report:

- Section 2 – Measure Description of this CASE Report provides a description of the measure and its background. This section also presents a detailed description of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.
- Section 3 – In addition to the Market Analysis section, this section includes a review of the current market structure. Section 3.2 describes the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions of the building standards, such as fire, seismic, and other safety standards, and whether technical, compliance, or enforceability challenges exist.
- Section 4 – Energy Savings presents the per-unit energy, demand reduction, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate per-unit energy, demand reduction, and energy cost savings.
- Section 5 - Cost and Cost Effectiveness includes a discussion and presents analysis of the materials and labor related to the lifecycle cost and cost-effectiveness analysis
- Section 6 – First-Year Statewide Impacts presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2022 code takes effect. This includes the amount of energy that would be saved by California building owners and tenants and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic by the State of California. Statewide water consumption impacts are also reported in this section.
- Section 7 – Proposed Revisions to Code Language concludes the report with specific recommendations with ~~strikeout~~ (deletions) and <u>underlined</u> (additions) language for the Standards, Reference Appendices, Alternative Calculation Manual (ACM) Reference Manual, Compliance Manual, and compliance documents.
- Section 8 – Bibliography presents the resources that the Statewide CASE Team used when developing this report.
- Appendix A: Statewide Savings Methodology presents the methodology and assumptions used to calculate statewide energy impacts.

- Appendix B: Embedded Electricity in Water Methodology presents the methodology and assumptions used to calculate the electricity embedded in water use (e.g., electricity used to draw, move, or treat water) and the energy savings resulting from reduced water use.
- Appendix C: Environmental Impacts Methodology presents the methodologies and assumptions used to calculate impacts on GHG emissions and water use and quality.
- Appendix D: California Building Energy Code Compliance (CBECC) Software Specification presents relevant proposed changes to the compliance software (if any).
- Appendix E: Impacts of Compliance Process on Market Actors presents how the recommended compliance process could impact identified market actors.
- Appendix F: Summary of Stakeholder Engagement documents the efforts made to engage and collaborate with market actors and experts.
- Appendix G: Nominal Energy Cost Savings presents the energy cost savings in nominal dollars by building type and climate zone.

2. Measure Description

2.1 Measure Overview

The intent of this proposal is to establish new mandatory Title 24, Part 6 covered process requirements for steam trap systems. This code change proposal would add new specificity to existing Section 120.6 “Mandatory Requirements for Covered Processes”. Historically, steam system components downstream of the steam generation equipment have not been included in Title 24, Part 6.

The proposed mandatory requirement applies to installations of a FDD system and strainer and blow-off valve assemblies in new construction, additions and alterations. Impacted systems for the proposed measure would be limited by connected steam boiler capacity and connected steam line operating pressure. Specifically, the proposed requirements would apply to all new construction, all additions and all steam trap alterations exceeding 30 pounds per square inch gauge (psig) of connected steam line pressure when the connected boiler capacity is greater than 2.0 million British thermal units per hour (MMBtu/hr). Systems that meet these pressure and capacity thresholds would need to install FDD systems and a strainer and blow-off valve assembly. The steam trap may have an integral strainer and blow-off valve, or the steam trap can be installed downstream within three feet of a strainer and blow-off valve assembly. “Steam trap alterations” is defined as the replacement of an existing steam trap.

The Statewide CASE Team is investigating the impacts of integral strainers on this proposal. Pending acquisition of integral strainer cost data, the cost modeling may be updated for the Final CASE Report. This consideration of integral strainer cost and market share and consequent updates to cost effectiveness have the potential to result in the code change proposal applying to systems operating at 15 psig and higher rather than the 30 psig threshold presented in the Draft CASE Report.

As this would be a Title 24, Part 6 requirement, it would also require additional compliance documentation. For new construction and additions subject to the proposed code change, a Nonresidential Certificate of Compliance and Nonresidential Certificate of Acceptance would be required. Steam trap alterations subject to the proposed code language would require the submittal of a Nonresidential Certificate of Installation.

The proposed measure does not impact steam trap type, size, or any other design specification of the component itself. The code proposal intends to reduce energy lost at the steam trap through two methods: (1) by expediting notification of a failure utilizing FDD system compared to a periodic manual assessment, and (2) through increasing the longevity of the steam trap life with the installation of a strainer and blow-off valve assembly which reduces the amount of debris entering the steam trap which could cause premature failure.

Due to the nature of the proposed measure and the uniqueness of impacted building types to which it is applied, standard building modeling prototypes do not apply. For this reason, custom energy savings estimates are calculated, and modeling assumptions are clearly defined and justified using a significant volume of research and stakeholder outreach. See Section 4 for detailed assumptions regarding energy savings analysis.

2.2 Measure History

Steam traps are mechanical devices installed in a steam system immediately after a heating process. A steam trap's primary function is to hold back steam until it condenses, giving up the steam's latent heat to the heating process. Additionally, steam traps let air and other non-condensables pass through to the condensate return system.

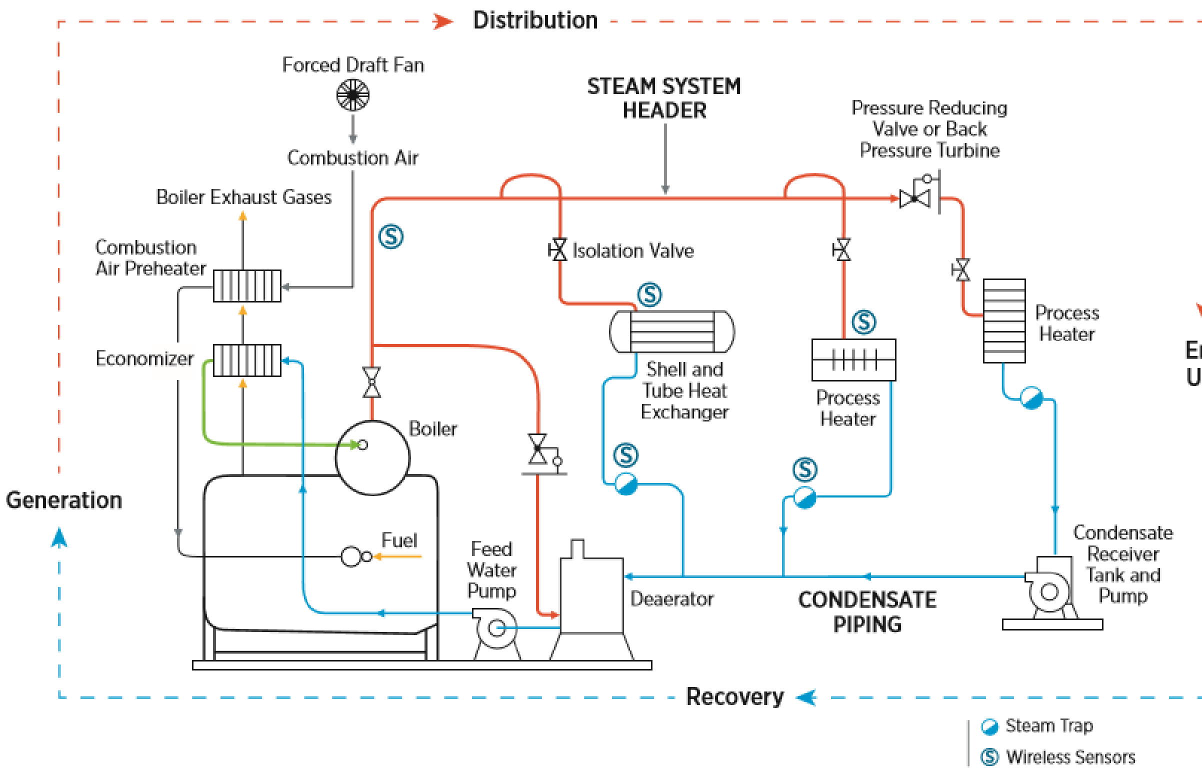

Figure 3: Steam system schematic.

Source: (Energy n.d.)

Steam traps can fail in either an open or closed position. If steam traps fail in a closed position, heating stops in the upstream device as the failure is often quickly identified and the trap is repaired. However, if steam traps fail in the open or partially open position, the upstream heating process is still being heated, and traps may go unrepaired for an extended period. In the failed open or partially open position, uncondensed steam passes through the trap and is released to the environment through the condensate return system, wasting energy.

Automatic steam trap monitoring systems require the installation of a sensor on each steam trap which detect when a steam trap failure has occurred. A central notification system alerts facility maintenance staff when the sensor indicates a trap failure. The intent of the system is to reduce the time that elapses between trap failure and failure identification, allowing maintenance staff to initiate the repair process more quickly. Commonly, FDD systems are installed to support identification of potential energy waste but are also installed on process critical applications, hard to access locations, or on steam traps that pose an elevated safety risk.

The proposed code supports an end-user's ability to reduce the overall time a steam trap is left in a failed position, specifically an open (blow-through) position. In an open blow-through position, steam is being lost to the environment and is thus wasted. Automatic steam trap monitoring provides notification of a failed steam trap (or other detected fault) sooner than would have occurred using the baseline practice of annual manual steam trap assessments.

Steam trap strainer installation improves the operating life of steam traps through the required installation of a strainer and blow-off valve assembly upstream of the steam trap to reduce the amount of debris and other contaminants that foul and over time lead to an otherwise premature failure of the steam trap.

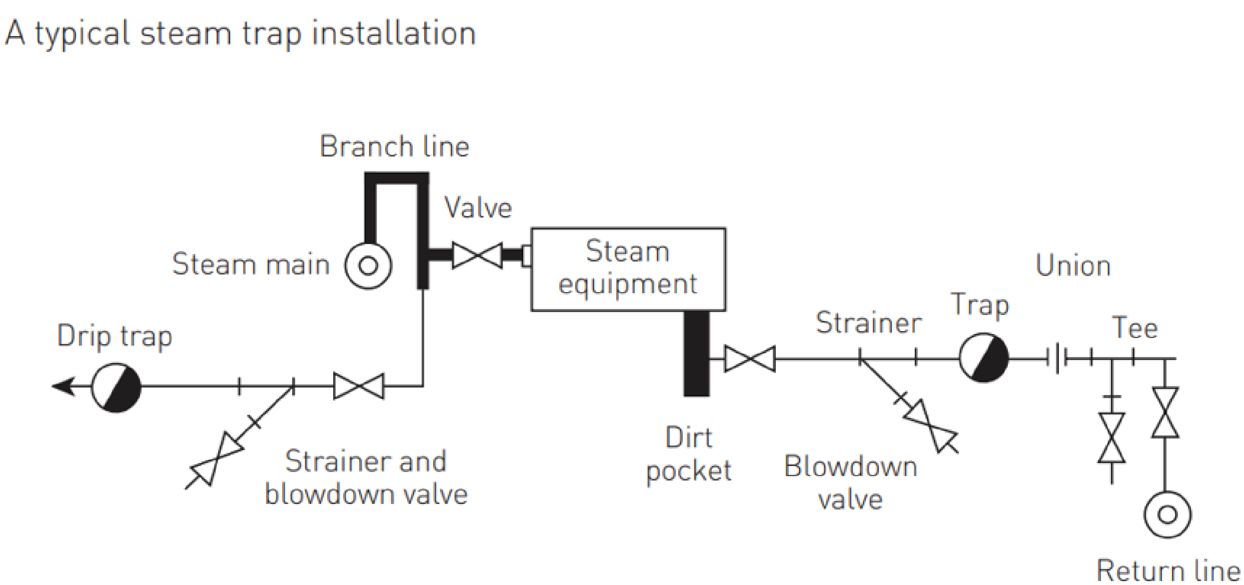

Figure 4: A typical steam trap, strainer and blow-off ("blowdown") valve assembly installation.

Source: (Traps n.d.)

The Statewide CASE Team investigated the potential for a FDD requirement in the 2016 Title 24, Part 6 code enhancement cycle. Due to the volume of proposed changes it was not selected for evaluation during that code cycle. Prior to 2016, the California IOUs explored FDD as a potential prescriptive rebate during the 2006-2008 prescriptive rebate program cycle. Ultimately the IOUs elected not to incorporate the measure into their prescriptive offerings. While it is believed that the proposed code change has not been previously incentivized through California IOU custom calculated incentive program channels, the California IOUs have provided custom incentives and prescriptive rebates for replacement and/or installation of steam traps for nonresidential building owners. Other Investor and Publicly Owned Utilities outside of California have provided financial incentive for end-users to install FDD systems. Prior limited California IOU incentive program support suggests relatively high energy savings persistence uncertainty due to the necessity of an operational response upon fault detection notification. There are many available case studies that document the energy savings potential and non-energy benefits of the code proposal measure when combined with adequate maintenance practices, per Table 5 below.

Table 5: Previous Reported Savings for Steam Trap Measures

Measure Type	Estimated Savings per Steam Trap	Source
Automatic Steam Trap Monitoring, Petrochemical	$2,109/year	Emerson (Emerson n.d.)
Automatic Steam Trap Monitoring, Military Base	$938/year	Armstrong (International n.d.)
Automatic Steam Trap Monitoring, Biotechnology	$946/year	Genetech (Stubbs n.d.)

2.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents would be modified by the proposed change. See Section 7 of this report for detailed proposed revisions to code language.

2.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of Title 24, Part 6 as shown below. See Section 7.2 of this report for marked-up code language.

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

Section 100.1(b) – Definitions: Recommends new or revised definitions for the following terms:

New definitions:

- “steam trap operating pressure” - the steam pressure entering the steam trap during normal design operating conditions.

SECTION 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES

- **Subsection 120.6(h):** The proposed code change adds mandatory requirements for FDD and steam trap strainer installation. Both the FDD and strainer requirements would apply to steam systems greater than 30 psig and with boiler capacity greater than 2.0 MMBtu/hr.

2.3.2 Summary of Changes to the Reference Appendices

This proposal would modify the sections of the Reference Appendices identified below. See Section 7.3 of this report for the detailed proposed revisions to the text of the reference appendices.

NONRESIDENTIAL APPENDICES

- **NA7.19 –Steam Trap Fault Detection Acceptance Tests:** The proposal would add an acceptance test that requires construction inspection and functional testing to confirm the steam trap fault detection system is installed and operating as required by the new mandatory requirements in Section 120.6(h).

2.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

The proposed code change would not modify the ACM Reference Manual.

2.3.4 Summary of Changes to the Nonresidential Compliance Manual

The proposed code change would modify the following sections of the Nonresidential Compliance Manual:

- Chapter 10, Covered Processes – section 10.12 Steam Traps, would need to be added.
- Chapter 13, Acceptance – Table 13-1 would be updated and the new acceptance test would need to be added in Section 13.4.4
- Appendix A, Compliance Documents– Three new compliance documents would need to be added to the list of documents; these documents are detailed in Section 7.6.
- Nonresidential Appendix NA7 – New Section NA7.19 would need to be added to define installation and acceptance requirements for nonresidential buildings and covered processes for the proposed measure.

See Section 7.5 of this report for the detailed proposed revisions to the text of the Compliance Manuals.

2.3.5 Summary of Changes to Compliance Documents

The proposed code change would modify the compliance documents listed below. Examples of the revised documents are presented in Section 7.6.

- A new compliance document would be required as the Statewide CASE Team is adding a new acceptance test for the proposed measure. NRCA-PRC-17-F for Steam Traps would need to be added to the compliance documents. This new document would be submitted to the enforcement agency that certifies the equipment and systems meet the acceptance requirements in NA7.19 in order to obtain an occupancy permit. The acceptance requirements would ensure that the installed equipment complies with the new standard.
- Certificate of Compliance document NRCC-PRC-E would need to be modified to reflect the new code requirements. The Certificate of Compliance documents are submitted to and approved by the appropriate enforcement agency with permit application.
- Certificate of Installation document NRCI-PRC-01-E would need to be modified to reflect the proposed new code requirements. Certificate of Installation documents are submitted to and approved by the appropriate enforcement agency.

2.4 Regulatory Context

2.4.1 Existing Requirements in the California Energy Code

Title 24, Part 6 does not include relevant existing requirements for steam distribution systems, steam traps, FDD systems, or steam trap strainer installation.

The Statewide CASE Team investigated potential regulatory ordinances and other 2022 Title 24, Part 6 code cycle proposals that may be impacted by the proposed adoption, however none were found to conflict with the proposed measure.

2.4.2 Relationship to Requirements in Other Parts of the California Building Code

There are no relevant requirements in other parts of Title 24, Part 6.

2.4.3 Relationship to Local, State, or Federal Laws

Statewide CASE Team research efforts including stakeholder outreach, web-based searches and examination of existing energy codes determined that there are no existing relevant local, state, or federal laws.

2.4.4 Relationship to Industry Standards

The Statewide CASE Team investigated industry standard requirements pertaining to steam distribution systems, steam traps and steam trap ancillary equipment as part of the CASE evaluation. It was determined that there are no relevant industry standard requirements which pertain to the proposed measure. There are many recommended best practices including strainer and blow-off valve assembly installation.

2.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced. This section describes how to comply with the proposed code change. It also describes the compliance verification process. Appendix E presents how the proposed changes could impact various market actors.

The activities that need to occur during each phase of the project are described below:

- **Design Phase:** The proposed code change would impact all new construction, all additions and all steam trap alterations. Steam system design firms are not historically accustomed to code related documentation and would require education on the process including design specification requirements and compliance documentation completion and submittal. Steam system design teams should be knowledgeable of the proposed mandatory requirements. The designer(s) need to identify which steam trap(s) in the design are subject to code requirements. Steam traps that are to comply with the code shall have the FDD system specified including the local control point fault detection sensor and communication equipment defined in Section 120.6(h)1A, the central control capability defined in Section 120.6(h)1B and the steam trap strainer installation components defined in Section 120.6(h)2. The designer is required to submit compliance document NRCC-PRC-E. Designers would need to collaborate with installers, as needed, to clearly communicate the design specifications that are needed to meet compliance requirements.
- **Permit Application Phase:** The proposed code change would impact the permit application phase for all new construction, all additions, and all steam trap alterations. Local building department jurisdictions are currently not, or minimally, accustomed to plan reviews of steam system design. As such, education on the compliance requirements defined in Section 120.6(h) and documentation review and approval would be necessary. The Certificate of Compliance document, NRCC-PRC-E, would need to be provided to plans examiners during the permit application phase. The plans examiner would need to be aware of the code

requirements and compliance document changes. The plans examiner would also need to understand how the code requirements should be integrated into the design, while ensuring that all existing codes and standards for subject facilities are being properly addressed. The plans examiner would review Certificate of Compliance documents and either provide guidance for not approved permit applications or provide approval to the design team.

- **Construction Phase:** The proposed code change would impact the construction phase. Installers and facility managers are not accustomed to code requirements for steam system design and are not familiar with FDD systems or steam trap strainer installations per code Section 120.6(h). For all new construction, all additions and all steam trap alterations subject to code compliance, the design and permit application phases would define the equipment specifications pertaining to code Section 120.6(h). Installer shall perform work detailed in the design documents to satisfy all code compliance. Upon completion of installed equipment, the installer or other Field Technician shall complete acceptance test(s) defined in Section NA7.19, as required.
- **Inspection Phase:** The proposed code change is expected to impact the inspection phase. The inspection phase for all new construction, all additions and all steam trap alterations would require submittal of Certification forms, NRCI-PRC-01-E and NRCA-PRC-17-F, to the local jurisdiction Building Department. NRCI-PRC-01-E and NRCA-PRC-17-F shall be filled out by the Field Technician. The installer could also act as the Field Technician role if the installer has been trained and certified to do so.

Currently there is no compliance process for steam trap installations. The compliance process phases are entirely new for each market actor. As there would be a learning curve necessary for each market actor involved in the compliance process, it is recommended to provide training to these market actors prior to the code change taking affect to reduce compliance challenges. The structure of the compliance process has been specifically tailored to mitigate compliance and enforcement hurdles. Separate and distinct verification requirements were developed as detailed in each phase description above.

Compliance and enforcement would require revisions and creation of multiple compliance documents; please see Section 7.6 for detailed descriptions of additions and revisions. Designers would need to collaborate with building departments during plan reviews to produce an approved Certificate of Compliance for new construction and additions of steam distribution systems. Designers and installers would need to collaborate to install equipment in compliance with the proposed Title 24, Part 6 requirements. Installers, facility managers, and other Field Technicians would need to work together to perform the construction and acceptance test verification requirements for all new construction, all additions and all steam trap alterations and produce the necessary Certification documents.

3. Market Analysis

3.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as impact individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during a public stakeholder meeting that the Statewide CASE Team held on November 7, 2019 (CASE Team 2019).

The FDD market is comprised of several manufacturers, distributors and manufacturers representatives, and installers. Manufacturers of FDD systems encompass a variety of backgrounds including steam trap manufacturers, control system integration providers, sensor and component manufacturers as well as other hot water and steam system component manufacturers (e.g., valves, heat exchangers, etc.). The Statewide CASE Team engaged with stakeholders who represent the spectrum of FDD systems equipment manufacturers. Additionally, the Statewide CASE Team reached out to numerous designers, installers, inspectors and end users to obtain their perspective(s) on the market, as well as solicit detailed technical and financial information to incorporate into the proposed measure evaluation.

The following companies have been identified as either component or system manufacturers of FDD systems: Armstrong International, Bitherm, Cypress Envirosystems, Emerson, Everactive, Honeywell, Spirax Sarco, and SteamIQ.

The FDD market is dominated by add-on component system packages that can be easily and non-invasively installed on most steam traps. Steam traps specifically designed for integral steam trap monitoring sensors are limited. Generally, FDD systems can be installed independent of the steam trap manufacturer, allowing for FDD from one manufacturer to be installed on most all other steam traps. With some FDD products there are limitations as to the manufacturer, model or operating pressure for which it could be equipped. Several automatic steam trap system representatives noted that installation on low pressure steam lines, steam lines below 15 psig, have a higher probability of fault detection error. Erroneous readings occur more easily due to the lower decibel difference associated with low differential pressure. Ultrasonic equipment measures sound at ultrasonic levels, as the differential sound level narrows it limits ultrasonic equipment accuracy. Therefore, the code proposal has defined the minimum applicable steam system operating pressure threshold to be no less than 15 psig. Upon final benefit-to-cost ratio evaluation the threshold steam system operating pressure was determined to be 30 psig.

End users have multiple options when it comes to FDD equipment selection, as opposed to being limited to a single applicable product. Automatic steam trap monitoring systems are relatively low complexity, but to date have had low market adoption. The incorporation of FDD systems into steam distribution system design is also limited and the measure is not often included in design specifications.

The Statewide CASE Team has identified three main channels for FDD system recommendation and selection. These channels include automatic steam trap system sales representatives, consulting engineers and end users. In addition to cost, safety and system/product reliability also drive the proposed code change and would drive adoption. Automatic steam trap monitoring systems are typically sold directly by the product manufacturer to the end user. Design and installation generally consist of two components: (1) a network communication feasibility study to determine adequate communication layout capability; this is generally performed by the FDD system manufacturers/distributors/vendors, and (2) the installation of FDD system equipment. Equipment consists of a (integrated, clamp-on) temperature or ultrasonic sensor device, power supply (either by internal battery or externally), communication equipment (gateway, repeater) via wireless or cellular network and connection to the central control system (integrated with facility, cloud based, remote monitor, etc.). System components can generally be installed by the manufacturer/distributor/vendor or by a third-party, including skilled end-user facility personnel.

The current steam trap system design process leaves the selection of components, including steam trap, strainers and blow-off valve assemblies, and isolation valves, as well as the specific positioning of the components during installation, open to the sales engineer or mechanical contractor performing the installation. Strainers and blow-off valve assemblies are often recommended and installed by the sales engineer or mechanical contractor as best practice for steam distribution systems. For new construction and additions, FDD systems and strainer installation would be the responsibility of the system designer, leveraging the expertise of the sales engineer for component sizing and selection.

3.2 Technical Feasibility, Market Availability, and Current Practices

Market adoption of steam trap FDD systems has been minimal. Based on market research and stakeholder discussions, FDD systems have been a viable technology since the mid-1990’s. The first-generation steam trap FDD systems used wired communication creating a complicated system of conduit. Early models came with a greater capital expense to both purchase and install in far stretching steam systems and carried a greater routine operations and maintenance burden compared with today's technology. With advances in communication technology over the past several decades, these obstacles have mostly been resolved. Advances in other technology, including improved sophistication of sensors (e.g., both ultrasonic and thermal), improved battery life expectancy (or in some cases battery-less systems), and communication privacy and security protocols have made for increasingly viable products from previous generations. As discussed previously, there are several FDD products available on the market, all of which offer their products nationally (some internationally). It should be noted that several of the manufacturers have offices in California and/or partner with vendors/distributors in California.

Additional training would be necessary for all involved market actors including system manufacturers (and their local distributors), designers, energy consultants, plan examiners, mechanical contractors/installers and Field Technicians to comply with the proposed code requirements. As most of these market actors are not currently familiar with FDD systems, a specific training would likely be needed for each market actor involved in the proposed code to ensure proper adherence and enforcement. Inspection and functional testing criteria are discussed in detail in Section7. End users may be minimally and temporarily affected by the functional testing acceptance requirement.

Automatic steam trap monitoring is a FDD-based tool. The system does not inherently reduce the energy consumption of steam systems on its own. Rather, the system provides instantaneous notification that a fault has occurred and a steam trap has failed. This early notification allows the end- user to address the problem sooner than the industry practice of periodic manual assessments for failed steam traps. The reduced time the steam trap is in failure mode directly correlates to energy savings. Based on stakeholder outreach and recommended industry standard practices, manual assessment typically occurs annually for code subject steam systems exceeding 15 psig. Although annual assessment is used as the baseline practice for this measure proposal it is worth noting that end-users may conduct manual assessment less frequently than an annual basis especially at steam operating pressure less than approximately 50 psig. Alternatively, high steam pressure systems may be manually assessed more frequently, in some cases as frequently as quarterly. Due to the nature of this energy savings measure, persistence would be highly dependent on the behavioral culture of the end-user. The presence of FDD does not inherently save energy or ensure persistence of energy savings. Maintenance practices in response to a failed steam trap notification would ultimately determine the realized energy savings. Additionally, FDD systems have their own set of maintenance requirements including power supply, sensor, and communication equipment subsystems. Automatic steam trap monitoring systems register a fault detection if one of the components becomes out of specification, thus indicating a maintenance procedure needs to occur. Without proper and timely maintenance, energy savings will not persist. The additional maintenance required for FDD systems was determined to be less than what is required for annual manual inspection. For energy savings associated with steam trap strainer installation to be realized, the assembly requires a periodic blowdown to ensure proper functionality and to increase the life expectancy of the downstream steam trap. This periodic blowdown requires additional periodic maintenance that otherwise would not exist in the absence of the strainer and blow-off valve equipment.

3.3 Market Impacts and Economic Assessments

3.3.1 Impact on Installer

Builders of residential and commercial structures are directly impacted by many of the measures proposed for the 2022 code cycle. It is within the normal practices of these businesses adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California's construction industry is comprised of about 80,000 business establishments and 860,000 employees (see Table 6).[1] In 2018, total payroll was $80 billion. Nearly 60,000 of these business establishments and 420,000 employees are engaged in the residential building sector, while another 17,000 establishments and 344,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

Table 6: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establishments	Employment	Annual Payroll (billions $)
Residential	**59,287**	**420,216**	**$23.3**
Residential Building Construction	22,676	115,777	$7.4

[1] Average total monthly employment in California in 2018 was 18.6 million; the construction industry represented 4.5 percent of 2018 employment.

Contractors			
Foundation, Structure, & Building Exterior	6,623	75,220	$3.6
Building Equipment Contractors	14,444	105,441	$6.0
Building Finishing Contractors	15,544	123,778	$6.2
Commercial	**17,273**	**343,513**	**$27.8**
Commercial Building Construction	4,508	75,558	$6.9
Foundation, Structure, & Building Exterior	2,153	53,531	$3.7
Building Equipment Contractors	6,015	128,812	$10.9
Building Finishing Contractors	4,597	85,612	$6.2
Industrial, Utilities, Infrastructure, & Other	**4,103**	**96,550**	**$9.2**
Industrial Building Construction	299	5,864	$0.5
Utility System Construction	1,643	47,619	$4.3
Land Subdivision	952	7,584	$0.9
Highway, Street, and Bridge Construction	770	25,477	$2.4
Other Heavy Construction	439	10,006	$1.0

Source: (State of California, Employment Development Department n.d.)

The proposed change to steam trap monitoring would likely affect industrial building construction builders and installers but would not impact firms that focus on construction and retrofit of residential or commercial buildings, utility systems, or public infrastructure. The effects on the industrial building industry would not be felt by all firms and workers, but rather would be concentrated in steam industry related subsectors. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 3.4 Economic Impacts.

3.3.2 Impact on System Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including Title 24, Part 6) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 7 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would minimally impact firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for steam trap monitoring to affect firms that focus on nonresidential industrial steam system construction.

There is not a North American Industry Classification System (NAICS)[2] code specific for energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[3] It is not possible to determine which business establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 7 provides an upper bound indication of the size of this sector in California.

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[2] NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

[3] Establishments in this sector include businesses primarily engaged in evaluating a building's structure and component systems and includes energy efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminates, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

Table 7: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billions $)
Architectural Services [a]	3,704	29,611	$2.91
Building Inspection Services [b]	824	3,145	$0.22

Source: (State of California, Employment Development Department n.d.)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;

b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

3.3.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including regulations enforced by the California Department of Occupational Safety and Health (Cal/OSHA). All existing health and safety rules would remain unaltered as a result of this proposed code change. Complying with the proposed code change is not anticipated to have adverse impacts on safety or health of the facility occupants or those involved with construction, commissioning, inspection, verification, and maintenance of the building or the general public. The measure proposal has been purposefully written for steam trap alterations to occur without adverse effect on safety and health, during the replacement process.

There are potentially various improvements to facility safety and health including reducing the occurrence of water hammer. A failed closed trap on a drip service would allow condensate to back up in a steam main which causes water hammer. Water hammer can be deadly if a pipe is damaged and steam escapes near persons. Timely repair of the failed trap resulting from the FDD system alerting the plant operator of equipment failure results in a higher probability of the failure being repaired before the failure manifests as water hammer.

The proposed code changes would apply to steam trap systems located in healthcare facilities.

3.3.4 Impact on Building Owners and Occupants

Industrial Buildings

The industrial building sector includes a wide array of building types, including factories, oil refineries, power generating facilities, slaughterhouses, and other facilities that primarily focus on manufacturing, processing, or assembly. Energy use in industrial buildings also varies considerably with electricity used for lighting, space cooling and conditioning, and refrigeration. Most electricity used in the industrial sector is purchased from utilities or other independent generators, but some industrial facilities also produce electricity either directly from other fuels or as a biproduct of their industrial processes. Industrial buildings use natural gas for heating water and for space heating. According to information published in the 2019 California Energy Efficiency Action Plan, the industrial sector (including agriculture) is responsible for 23 percent of California's total annual energy use (Kenney 2019). Most of this energy is used in industrial processes and the 2019 California Energy Efficiency Action Plan does not attempt to estimate the relatively small proportion of industrial energy used for lighting, water and space heating, or other building-specific purposes. The diversity of building and business types within this sector creates a challenge for disseminating information on energy and water efficiency solutions.

Commercial Buildings

The commercial building sector includes a wide array of building types, including offices, restaurants and lodging, retail, and mixed-use establishments, and warehouses (including refrigerated) (Kenney 2019). Energy use by occupants of commercial buildings also varies considerably with electricity used primarily for lighting, space cooling and conditioning, and refrigeration. Natural gas consumed primarily for heating water and for space heating. According to information published in the 2019 California Energy Efficiency Action Plan, there is more than 7.5 billion square feet of commercial floor space in California and consumes 19 percent of California's total annual energy use (Kenney 2019). The diversity of building and business types within this sector creates a challenge for disseminating information on energy and water efficiency solutions, as does the variability in sophistication of building owners and the relationships between building owners and occupants.

Estimating Impacts

Building owners and occupants would benefit from lower energy bills. As discussed in Section 3.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2022 code cycle to impact building owners or occupants adversely.

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

It is expected that manufacturers and distributors of FDD systems would be impacted by the proposed code change. It is anticipated that a significant increase in FDD system product demand would be incurred at a rate of greater than 4,000 new control points annually.

3.3.6 Impact on Building Inspectors

Table 8 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed code adoption would have minimal impact on employment of building inspectors. Many building departments have specialized groups for industrial buildings and/or covered processes from the energy code. Currently the energy code does not cover steam related systems. Therefore, the Statewide CASE Team, anticipates the proposed code adoption would impact the scope of building inspector roles when conducting energy efficiency inspections. Additional training would be necessary for building department inspectors.

Table 8: Employment in California State and Government Agencies with Building Inspectors

Sector	Govt.	Establish ments	Employ ment	Annual Payroll (millions $)
Administration of Housing Programs[a]	State	17	283	$29.0
	Local	36	2,882	$205.7
Urban and Rural Development Admin[b]	State	35	552	$48.2
	Local	52	2,446	$186.6

Source: (State of California, Employment Development Department n.d.)

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.
b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

3.3.7 Impact on Statewide Employment

As described in Sections 3.3.1 through 3.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any sector of the California economy. This is not to say that the proposed change would have minimal impact on employment in California. In Section 3.4, the Statewide CASE Team estimated the proposed change in steam trap monitoring would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in steam trap monitoring would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

3.4 Economic Impacts

For the 2022 code cycle, the Statewide CASE Team used the IMPLAN model software, along with economic information from published sources, and professional judgement to developed estimates of the economic impacts associated with each proposed code changes.[4] While this is the first code cycle in which the Statewide CASE Team develops estimates of economic impacts using IMPLAN, it is important to note that the economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. In addition, the IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspect of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the Statewide CASE Team believes the economic impacts presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by industrial contractors, energy consultants and designers, and building inspectors. The Statewide CASE Team does not anticipate that money saved by businesses or other organizations affected by the proposed 2022 code cycle regulations would result in additional spending by those businesses.

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[4] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

Table 9: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income (millions $)	Total Value Added (millions $)	Output (millions $)
Automatic Steam Trap Monitoring				
Direct Effects (Additional spending by Commercial Builders)	86	$5.70	$7.56	$12.50
Indirect Effect (Additional spending by firms supporting Commercial Builders)	19	$1.36	$2.17	$4.19
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	38	$2.11	$3.78	$6.17
Steam Trap Strainer Installation				
Direct Effects (Additional spending by Commercial Builders)	13	$0.87	$1.15	$1.90
Indirect Effect (Additional spending by firms supporting Commercial Builders)	3	$0.21	$0.33	$0.64
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	6	$0.32	$0.57	$0.94
Total Economic Impacts	**165**	**$10.57**	**$15.56**	**$26.33**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

Table 10: Estimated Impact that Adoption of the Proposed Measure would have on the California Building Designers and Energy Consultants Sectors

Type of Economic Impact	Employment (jobs)	Labor Income (millions $)	Total Value Added (millions $)	Output (millions $)
Automatic Steam Trap Monitoring				

Direct Effects (Additional spending by Building Designers & Energy Consultants)	2	$0.23	$0.22	$0.40
Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consult.)	1	$0.09	$0.13	$0.20
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	2	$0.10	$0.17	$0.28
Steam Trap Strainer Installation				
Direct Effects (Additional spending by Commercial Builders)	1	$0.13	$0.13	$0.23
Indirect Effect (Additional spending by firms supporting Commercial Builders)	1	$0.05	$0.07	$0.12
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	1	$0.06	$0.10	$0.16
Total Economic Impacts	**8**	**$0.66**	**$0.83**	**$1.39**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

Table 11: Estimated Impact that Adoption of the Proposed Measure would have on California Building Inspectors

Type of Economic Impact	Employment (jobs)	Labor Income (millions $)	Total Value Added (millions $)	Output (millions $)
Automatic Steam Trap Monitoring				
Direct Effects (Additional spending by Building Inspectors)	2	$0.21	$0.25	$0.30
Indirect Effect (Additional spending by firms supporting Building Inspectors)	0	$0.02	$0.03	$0.05
Induced Effect (Spending by employees of Building Inspection Bureaus and Departments)	1	$0.07	$0.12	$0.20
Steam Trap Strainer Installation				
Direct Effects (Additional spending by Commercial Builders)	1	$0.12	$0.14	$0.17
Indirect Effect (Additional spending by firms supporting Commercial Builders)	0	$0.01	$0.02	$0.03
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	1	$0.04	$0.07	$0.12
Total Economic Impacts	**5**	**$0.47**	**$0.63**	**$0.86**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

3.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the proposed measures would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team’s proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in Section 3.4 would lead to modest changes in employment of existing jobs.

There would likely be negligible overall job creation or elimination, and creation would outweigh elimination. There are both positive and negative scenarios presented below.

Positive scenarios involve creation of subsector jobs to design, sell/distribute, plans review, install, and test in accordance with code. Holistically compared to the California population this would be negligible, but in comparison to the existing subsegments it would likely be quantifiable. This impact will be further evaluated through the program cycle.

The worst-case scenario would be elimination of jobs that could occur if the cost burden is too great and forces the closure of a manufacturer. There is an extremely low probability of this occurring.

3.4.2 Creation or Elimination of Businesses in California

As stated in Section 3.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to steam trap installations at operating pressures greater than 30psig, which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

3.4.3 Competitive Advantages or Disadvantages for Businesses in California

The proposed code changes would apply to all process steam systems larger than 2 MMBtu/hr and with operating pressures higher than 30 psig in California. This code requirement would apply in all applicable buildings regardless of whether the business that is occupying the building is incorporated inside or outside of the state.[5] Additionally the lifecycle energy cost savings are greater than the measure cost so the installation of the measure in financially beneficial. Therefore, the Statewide CASE Team does not anticipate that the proposed measure regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

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[5] Gov. Code, §§ 11346.3(c)(1)(C), 11346.3(a)(2); 1 CCR § 2003(a)(3) Competitive advantages or disadvantages for California businesses currently doing business in the state.

There would not necessarily be any advantage due to geography. Most manufacturers are national (or international companies). Realized energy savings translates to dollars saved for end-users, could elect to reinvest into other applications that support the local and/or state economies.

3.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[6] As Table 12 shows, between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, with an average of 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

Table 12: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits
2015	609.3	1,740.4	35%
2016	456.0	1,739.8	26%
2017	509.3	1,813.6	28%
2018	618.3	1,843.7	34%
2019	580.9	1,827.0	32%
		5-Year Average	**31%**

Source: (Federal Reserve Economic Data n.d.)

Estimated increase in investment in California:

Change in Proprietor Income * 0.31 = $449,248

[6] Net private domestic investment is the total amount of investment in capital by the business sector that is used to expand the capital stock, rather than maintain or replace due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

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

The Statewide CASE Team does not expect the proposed code changes would have a measurable impact on the California's General Fund, any state special funds, or local government funds.

State government already has budget for code development, education, and compliance enforcement. While state government would be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals.

All proposed code changes to Title 24, Part 6 would result in changes to compliance determinations. Local governments would need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2022 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training and resources provided by the IOU Codes and Standards program (such as Energy Code Ace). As noted in Section 2.5 and Appendix E, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

3.4.6 Impacts on Specific Groups of Californians

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes that there is the potential that a proposed code change may result in unintended consequences. The proposed code change was determined to not have a direct impact on any specific group.

4. Energy Savings

4.1 Key Assumptions for Energy Savings Analysis

The Time Dependent Valuation (TDV) factors used in the analysis for the Draft CASE Report were provided by the Energy Commission in May 2020 along with an indication that they were likely the factors that would be released in June 2020. They include the 15 percent retail adder, methane leakage, and 20-year global warming potential values.

To calculate the unit first-year energy savings and statewide energy savings potential for the proposed covered process code addition, the Statewide CASE Team developed a custom spreadsheet-based energy savings calculation. This analysis was done independent of climate zone as process loads are negligibly impacted by ambient conditions. The analysis does not utilize the California Building Energy Code Compliance (CBECC) software, as process loads are not covered in the modeling software prototype buildings due to their highly variable nature. Key variables and their values are described in the list below. Key variables were ascertained from open-ended interviews with identified stakeholders, and documented in Appendix F. The proposed measure energy savings analysis is based on Napier's Equation for steam flow through an orifice. The following list of key variables, source for assumption, and average values were used in the analysis:

- Napier's Equation (Emerson 2013): $W = 24.4 \times P_{abs} \times D^2$

  where,

  - W = Steam Loss, pounds per hour
  - P_{abs} = Absolute Pressure (pounds per square inch absolute)
  - D = Steam trap orifice diameter (inches)
- Specific enthalpy for water from liquid to gas (British Thermal Units per pound)
- Failure rate (i.e., steam trap effective useful life) is four years (Published data and stakeholder feedback)
- Failure position is 66.7 percent of traps fail in the open position (Stakeholder feedback)
- De-rate steam trap failed open leakage rate is 50 percent (U.S. DOE guidance and stakeholder feedback)
- Boiler thermal efficiency is 83 percent (California statewide workpaper)
- Steam trap inlet pressure bin data (Manufacturer data set(s))

- Common steam trap orifice diameter by pressure bin (Manufacturer data set(s))
- Baseline manual survey rate is annually (Stakeholder feedback)
- Time between trap failure and failure identification is six months (Stakeholder feedback)
- A "follow-through" rate to account for the maintenance process not being initiated immediately upon failure identification of 95 percent
- Average operating hours of 6,730 hours per year is assumed, the average between facilities operating 3-shifts (allowing for one week of system downtime) and facilities running 4,860 hours annually.
- For strainer operation, the Statewide CASE Team assumes the following adjustments are made to the model when a strainer is installed:
- Steam trap effective useful life improves from four to six years between failures (Stakeholder feedback)

4.2 Energy Savings Methodology

4.2.1 Energy Savings Methodology Per Steam Trap

To assess the energy, demand, and energy cost impacts, the Statewide CASE Team compared baseline defined industry and design practices to design practices that would comply with the proposed code language requirements. There are no existing Title 24, Part 6 or other industry code requirements that regulate steam trap design pertaining to energy usage. The Statewide CASE Team determined current design practices from which to model energy consumption based on published documentation and stakeholder feedback. As noted in the introduction of the report, the Statewide CASE Team is continuing to engage with stakeholders and is requesting additional feedback on the underlying assumptions presented in Table 13 of this section.

The proposed conditions are defined as the design conditions that are required to comply with the proposed code addition. Specifically, the proposed code would reduce the duration between steam trap failure and identification of the trap failure with the addition of an automatic stream trap monitoring system.

The proposed code change would also reduce the frequency of steam trap failures through steam trap strainer installation, which would be a requirement for new construction and additions to install a strainer and blow-off valve for each steam trap, and for alterations upon steam trap replacement.

It should be noted that for energy savings to be realized the end-user must respond to the FDD system fault detection notification by initiating a repair or replacement of the identified failed steam trap.

Stakeholder feedback revealed that FDD technologies struggle to identify failed steam traps at operating pressures below 15 psig (29.7 psia). Thus, the analysis for savings and cost effectiveness was performed for inlet pressures at or greater than 30 psig (44.7psia). The methodologies below describe first how individual trap savings then average savings were determined. The assumptions in Table 13 are based on research and stakeholder outreach.

The methodology to extrapolate individual trap (a given inlet pressure and orifice diameter) savings to an average steam trap, as well as a statewide savings estimate, is as follows:

- Step 1: Calculate annual steam trap energy savings based on assumptions detailed in Table 13: Calculation Assumptions.
- Step 2: For each pressure bin, calculate savings based on each pressure bin's corresponding average steam trap orifice diameter. Bin data that tabulates the relative presence of steam traps at a given operating pressure were obtained from stakeholder feedback.
- Step 3: Calculate the weighted average based on the relative prevalence of steam traps operating at each pressure bin, based off stakeholder provided data sources

To calculate the average strainer energy savings:

- Step 1: Repeat steps one through three above with the calculation adjusted for the strainer and blow-off valve assembly requirement.

Table 13: Calculation Assumptions

Value	Variable Name	Description
24.24	-	Napier's Equation coefficient
Varies	W	Napier's Equation, result varies by pressure and orifice diameter
0.667	B	Rate at which traps fail in open position
0.5	C	Orifice size de-rate factor (FEMP FTA - DOE/EE-0193)
0.83	G	Boiler thermal efficiency percentage (workpaper)
15	J	Analysis period, in years
4		Average steam trap life, in years
3.75	$F_{\text{steam trap}}$	Number of failures; expected number of times a steam trap will fail during the analysis period (15/4=3.75)
2.5	F_{strainer}	Number of failures; expected number of times a steam trap will fail during the analysis period with a strainer present upstream (15/6=2.5)
0.5	E	Failure period: expected time in years between when a steam trap

Value	Variable Name	Description
		fails and when the failure is identified without FDD (based on annual manual inspections)
0.95	I	“Follow-through” rate, account for the maintenance process not being initiated immediately upon failure identification
6,730	Annual Hours	Operating hours, the average operating hours between facilities with 3-shifts (allowing for one week of system downtime) and facilities running 4,860 hours annually.
Varies	P_{abs}	Absolute pressure, ranges from 44.7 to 614.7 pounds per square inch absolute
Varies	D	Steam trap orifice diameter, ranges from 1/32 to 1/2 inches
Varies	H_{fg}	Steam energy content (Btu/pound-mass), based on the steam operating pressure
100,000	-	Conversion (Btu/therm)

4.2.1.1 Per Unit Energy Savings Methodology - FDD

The following equation is used to estimate the annual energy savings (AES_{FDD}) for FDD:

$$AES_{ASTM} = \frac{(24.24 \times P_{abs} \times D^2 \times H_{fg} \times Annual\ Hours)}{G \times J \times 100{,}000 \frac{Btu}{therm}} \times B \times C \times E \times F_{steam\ trap} \times I$$

This equation was developed by the Statewide CASE Team to estimate lifecycle and first year savings. Measure savings are largely driven by variables E and $F_{steam\ trap}$. Variable E represents the time between when a steam trap fails and when, on average and based on stakeholder feedback, the process of repair can be initiated. The analysis assumes that annual inspection of steam traps is the baseline, and six months is the average time between trap failure and failure identification, assuming a random distribution of failure events. This is different than the “time-to-repair”, which would be how much time it takes to repair a steam trap once the failure is identified, which is assumed to be the same in both the base- and proposed-cases.

Steam trap failure can be highly variable and dependent on many factors, such as operating conditions, appropriate trap selection for the application, and so on. Although for variable $F_{steam\ trap}$ a 4-year average life is assumed, it is not uncommon to see traps that last just a few months or traps in operation for 10 or more years. For this analysis, the first repair occurs in the beginning of year 4, the second in year 8, with the third failure occurring in year 12. The partial failure may occur outside the analysis period, but with 25 percent of traps failing each year, some replacements would still be expected to occur after year 12.

Bin data that tabulates the relative presence of steam traps at a given operating pressure were obtained from stakeholder feedback. Average steam trap orifice diameters for each pressure bin were provided by a stakeholder and are assumed to represent the most commonly selected steam trap orifice for a given pressure bin.

Steam Trap Loss and Energy Loss Rate (Full Open)

The mass flow of steam, W, in units of pounds per hour, that leaks through an open trap is a function of the orifice size and the absolute pressure of the steam and can be calculated using Napier's Equation as given below:

W = 24.24 x Pabs x D^2

W = 24.24 x (Pga + 14.7) x D^2

Pabs = System Pressure, Absolute Pressure, psia

Pga = Steam pressure gauge, psig

D = orifice diameter, in

14.7 = Atmospheric Pressure (psi)

The energy content of steam leaking through an open trap, E_{loss}, is given by the following equation and is in units of Btu/hr.

E_{loss} = W x h_{fg}

h_{fg} = specific enthalpy change fluid to gas, Btu/lb

The following equations describe how energy savings are calculated on a steady state basis. Steam traps are assumed to have a 25 percent chance of failing each year (four-year typical steam trap life). The base case scenario assumes that an industrial facility has a steam trap inspection program that checks all steam traps once per year. Since the traps can fail randomly anytime during this year interval, it is anticipated for steam traps that have failed open, this failure is not detected for six months on average. When steam traps fail, two-thirds of the time they fail open and one-third of the time they fail closed. If the steam trap fails closed, heating ceases and is typically repaired quickly, nonetheless the closed trap does not waste energy. The energy savings from steam trap FDD results from the two-thirds of the traps that fail open. Additionally, steam traps can fail in a range from full open to barely open, thus it was assumed that traps that fail open are failed half open (steam is exiting through half of the orifice area).

The annual energy savings, ES, in units of therms/yr, associated with FDD failed open can be expressed by the following equation with the variables described in Table 14 below.

$$ES = E_{loss} \times A \times B \times C \times D \times E \times Hr / Eff / BpTh$$

Table 14: Factors Used to Calculate Steam Trap FDD Annual Energy Savings, ES

Variable	Value	Description
A	0.667	Rate of Trap Failure in Open Position
B	0.5	Conservative Assumption on Actual Orifice Size (FEMP FTA - DOE/EE-0193)
C	95%	Follow-Thru Rate
	4	years, average trap life (3-5 years)
D	0.25	fraction of traps failing per year
E	0.5	avoided period of delay to repair, fraction of year
Hr	6,730	annual operating hours, yr
Eff	0.83	Boiler Combustion Efficiency, assumed
BpTh	100,000	Btu per therm

Results of the per unit energy savings, energy cost savings, cost effectiveness, and water savings calculations for steam trap FDD are presented in Table 17.

4.2.1.2 Per Unit Energy Savings Methodology – Steam Trap Strainer

The following equation is used to estimate the annual energy savings (AES_{STS}) for the steam trap strainer installation consideration:

$$AES_{STS} = \frac{(24.24 \times P_{abs} \times D^2 \times H_{fg} \times Annual\ Hours)}{G \times J \times 100{,}000 \frac{Btu}{therm}} \times B \times C \times E \times \left(F_{steam\ trap} - F_{strainer}\right) \times I$$

The savings is the difference between the number of steam trap failures estimated for FDD ($F_{steam\ trap}$ = fifteen year analysis period divided by 4 year trap life or three and three quarter failures) and the improvement to steam trap life that comes with the installation of a strainer assembly ($F_{strainer}$ = fifteen year analysis period divided by six year trap life or two and a half failures). The reduction in failures is an estimate based on stakeholder conversations that strainers are useful for extending the operating life of the equipment they are protecting, and can prevent material that might block or damage steam trap valve seals from doing so, which is one of the biggest modes of failure for steam traps. Based on stakeholder feedback, strainer and valve assemblies are expected to have a seven and a half-year EUL.

The energy impacts of the proposed code change do not vary by climate zone. Since savings do not vary by climate zone, the Statewide CASE Team used the statewide average TDV factors when calculating energy and energy cost impacts.

Per-unit energy impacts for covered processes are presented in savings per average steam trap unit. This step enables a calculation of statewide savings using the size of the industrial steam using market in California.

Results of the per unit energy savings, energy cost savings, cost effectiveness, and water savings calculations for steam trap strainer installation are presented in Table 18 (new construction and additions) and Table 19 (alterations).

To ensure the measure remained cost effective, it became necessary to examine the minimum pressure bin that could be included the weighted average per trap savings, and yet ensure a benefit-to-cost ratio greater than one. In this case, pressure bins below 30 psig resulted in the weighted average energy savings decreasing and the proposed measures were no longer cost effective. The first threshold to determine when the requirements apply was then developed to clarify that the proposed requirements would apply to steam systems operating at 30 psig and above. The second threshold was identified while developing the lifecycle cost model for the measures. It became evident that the cost of equipment that could be shared by multiple steam trap monitoring sensors (the communication gateway) prevented the measure from being cost effective if only one trap at a facility was replaced during the 15-year period of analysis. A close look at how shared costs could be divided amongst multiple monitoring sensors suggested a reasonable steam system size of 30 units as being required to ensure implementation costs remained cost effectiveness. However, enforcement of a “Steam Trap Quantity” threshold is not possible, and an analysis was carried out to identify a minimum total combined connected boiler input rating capacity that would likely have the required 30 steam traps. That exception was calculated to be a steam system with a total combined connected boiler input rating capacity of 2.0 MMBtu/hr.

Table 15 presents the analysis performed to develop the total combined connected boiler input rating capacity exception.

Table 15: Minimum Total Combined Connected Boiler Input Capacity Exception Analysis

30	FDD Quantity
4	Average life expectancy
7.5	Average failed at given time
3,868	Average steam loss of failed trap per year, 100% open trap [therms/yr]
6,730	Modeled Operating Hours
0.667	Rate of Trap Failure in Open Position
0.5	Conservative Assumption on Actual Orifice Size (FEMP FTA - DOE/EE-0193)
9,674	Average steam loss of failed traps per year [therms/yr]
7%	Baseline Percent loss of Boiler Capacity
138,194	Annual Boiler Usage [Therms]

2,000,000	Boiler Input Capacity [Btu/hr]

4.2.2 Statewide Energy Savings Methodology

The per-unit energy impacts were extrapolated to statewide impacts using nationwide industrial steam use data modified to reflect the California market ((5) 2019). This data reflects an estimation of the total natural gas use statewide that is used to generate steam in the industrial sector. From this existing consumption data, an evaluation of forecasted annual new construction/addition code-triggering boiler installations was determined. Finally, the Statewide CASE Team estimated the number of steam trap installations that would occur to meet the code-triggering boiler installation requirements.

For FDD alterations, the Statewide CASE Team examined the adoption of steam trap replacements or repairs funded by investor owned utility rebate programs (Itron 2010). The annual average replacement was 7,959 traps during each year of the evaluation, which the Statewide CASE Team and interviewed stakeholders found reasonable.

For steam trap strainer installation, the quantity of steam traps estimated for the automatic monitoring measure were modified, based on stakeholder feedback, to reflect the actual new opportunities for savings that would result from implementing the measure, considering that strainer assembly installation is considered a best practice and in many cases a standard practice. Generally, stakeholder feedback suggested that 40 percent of existing steam traps have an associated strainer, and 80 percent of new traps are designed with strainers.

Appendix A presents additional information about the methodology and assumptions used to calculate statewide energy impacts.

4.3 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per unit are presented below and are expected to be the same for both new construction and alterations. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates.

To determine a final average per-unit savings, the Statewide CASE Team used manufacturer’s data, obtained from targeted stakeholder engagement, that provides the binned operating pressures of the steam traps in their national database, which was assumed to be representative of the California market. The Statewide CASE Team assumed a “common” orifice diameter (provided by stakeholder outreach) at each of the binned pressures, and weighted the savings calculated at each orifice diameter and pressure by the overall percentage of steam traps in the dataset that operated at the given pressure. These savings represent the energy that would no longer be lost due to failed traps with the implementation of FDD or the increased system lifetime that accompanies strainer installation.

Using the following equation, a single “per steam trap” savings value was estimated for the entire steam trap population:

$$
\begin{aligned}
&Average\ Trap\ Savings\\
&\quad = \sum [(Trap\ Savings\ @\ X\ inlet\ pressure, Y\ orifice\ diameter\\
&\quad \times Percentage\ of\ Steam\ Traps\ at\ X\ inlet\ pressure\ in\ Sample\ )\\
&\quad +\ (Trap\ Savings\ @\ A\ inlet\ pressure, B\ orifice\ diameter\\
&\quad \times Percentage\ of\ Steam\ Traps\ at\ B\ inlet\ pressure\ in\ Sample\ )\ + \cdots]
\end{aligned}
$$

Table 16 presents the Inlet Pressures, Standard Orifice Diameters and weighting of the overall steam trap market that the given inlet pressure and standard orifice diameter pair represents.

Table 16: Energy Savings Per Steam Trap

Inlet Pressure [psig]	Standard Orifice Diameter (inches)	Population of Steam Trap Market at Inlet Pressure [%]	Automatic Monitoring First Year Energy Savings (therms)	Strainer Installation First Year Energy Savings [therms]
30	3/16	9.7%	114	38
45	5/32	10.7%	104	35
60	5/32	20.6%	128	43
80	5/32	8.7%	161	54
100	5/32	7.9%	192	64
125	1/8	8.6%	148	49
150	1/8	16.9%	172	57
200	7/64	7.7%	168	56
250	7/64	4.9%	202	67
300	7/64	1.0%	236	79
400	5/64	0.6%	153	51
500	5/64	0.5%	184	61
600	3/32	2.2%	306	102
Weighted Average Savings [therms/steam trap]:			**153**	**51**

For FDD, weighted average per-unit savings for the first year is expected to 153 therms/yr. There are no expected electricity or electricity demand reductions.

For steam trap strainer installation, weighted average per-unit savings for the first year is expected 51 therms/yr. There are no expected electricity or electricity demand reductions.

These savings are dependent on the operational behavior of the end-users implementing the measure. Automatic steam trap monitoring provides immediate notification of steam trap failure; however, steam trap repair must still be completed for energy savings to accrue. A “follow-through” rate has been applied to the Automatic Monitoring Energy Savings to account for the maintenance process not being initiated immediately upon failure identification.

Results of the per unit energy savings, energy cost savings, cost effectiveness, and water savings calculations for steam trap FDD and steam trap strainer installation are presented in Table 17, Table 18, Table 19.

See Section 5 of this report for the methodology for calculating energy cost savings, incremental costs, and cost effectiveness. The energy cost savings (ESC) was determined using the following equation:

ESC = ES x PV$pth

Where,

PV$pth = 2022 TDV present valued dollars per therm of the 15-year period of analysis, PV$20.55/therm

For steam trap FDD, the benefit-to-cost ratio is based on a lifecycle cost of $2,648 for the installed cost of the FDD device and maintenance over 15 years. The savings and costs are shown for different steam pressures. Typical steam trap orifice sizes and their market share with respect to steam pressure was provided by one of the steam trap manufacturers. Using this information, the Statewide CASE Team calculated typical steam losses with respect to pressure and a weighted cost savings for all systems with pressures of 30 psig and above.

See Section 6.3 for assumptions about water savings and embedded electricity savings associated with reduced water use. Embedded electricity savings were not included in the cost-effectiveness calculations.

Table 17: Steam Trap Monitoring – Per Unit Energy Savings, Energy Cost Savings, Cost Effectiveness, and Water Savings Results – New Construction, Additions, and Alterations

Gauge Pressure (psig)	Orifice Diameter (inch)	Market Share	Open Trap Steam Loss [W] (lb/hr-trap)	Specific Enthalpy Change Fluid to Gas [hfg] (Btu/lb)	Annual Open Trap Energy Loss [Eloss] (Btu/hr-trap)	Annual Energy Savings [ES] (therms/ yr- trap)	15-Year Present Valued Cost Savings [ECS] (2023 PV$/yr-trap)	15-Year Incremental Cost (2023 PV$/trap)	Benefit -to-Cost Ratio	Annual Water Savings (gallons/ yr-trap)	Annual Embedded Electricity Savings (kWh/yr-trap)
15	3/16	-	25.31	945.7	23,936	77	$1,579	$2,648	0.6	404	1.44
30	3/16	9.7%	38.09	929.1	35,392	114	$2,335	$2,648	0.88	609	2.17
45	5/32	10.7%	35.33	915.9	32,359	104	$2,135	$2,648	0.81	565	2.01
60	5/32	20.6%	44.21	904.9	40,003	128	$2,640	$2,648	1.00	706	2.52
80	5/32	8.7%	56.04	892.2	50,002	161	$3,299	$2,648	1.25	896	3.19
100	5/32	7.9%	67.88	881	59,801	192	$3,946	$2,648	1.49	1,085	3.87
125	1/8	8.6%	52.91	868.7	45,964	148	$3,033	$2,648	1.15	845	3.01
150	1/8	16.9%	62.38	857.6	53,497	172	$3,530	$2,648	1.33	997	3.55
200	7/64	7.7%	62.26	838	52,173	168	$3,443	$2,648	1.30	995	3.55
250	7/64	4.9%	76.76	820.7	62,995	202	$4,157	$2,648	1.57	1,227	4.37
300	7/64	1.0%	91.26	805	73,462	236	$4,847	$2,648	1.83	1,458	5.20
400	5/64	0.6%	61.35	777	47,672	153	$3,146	$2,648	1.19	980	3.50
500	5/64	0.5%	76.15	751.9	57,257	184	$3,778	$2,648	1.43	1,217	4.34
600	3/32	2.2%	130.96	728.8	95,444	306	$6,298	$2,648	2.38	2,093	7.46
			Weighted Average Values > 30 psi:	**878.7**	**47,697**	**153**	**$3,147**	**$2,648**	**1.19**	**867**	**3.09**

Table 18: Steam Trap Strainer Installation – Per Unit Energy Savings, Energy Cost Savings, Cost Effectiveness, and Water Savings Results – New Construction and Additions

Gauge Pressure (psig)	Orifice Diameter (inch)	Market Share	Open Trap Steam Loss [W] (lb/hr-trap)	Specific Enthalpy Change Fluid to Gas [hfg] (Btu/lb)	Eloss, Open Trap Energy Loss, Btu/hr-trap	Annual Open Trap Energy Loss [Eloss] (Btu/hr-trap)	Annual Energy Savings [ES] (therms/ yr- trap)	15-Year Present Valued Cost Savings [ECS] (2023 PV$/ trap)	15-year Incremental Cost (2023 PV$)	Benefit -to-Cost Ratio	Annual Water Saved (gallons /yr-trap)	Annual Embedded Electricity Savings (kWh/yr-trap)
15	3/16	-	25.31	945.7	23,936	1,941	26	$526	-	-	135	0.48
30	3/16	9.7%	38.09	929.1	35,392	2,870	38	$778	$699.78	1.11	203	0.72
45	5/32	10.7%	35.33	915.9	32,359	2,624	35	$712	$653.56	1.09	188	0.67
60	5/32	20.6%	44.21	904.9	40,003	3,244	43	$880	$625.04	1.41	235	0.84
80	5/32	8.7%	56.04	892.2	50,002	4,054	54	$1,100	$645.16	1.70	299	1.06
100	5/32	7.9%	67.88	881	59,801	4,849	64	$1,315	$645.16	2.04	362	1.29
125	1/8	8.6%	52.91	868.7	45,964	3,727	49	$1,011	$645.16	1.57	282	1.00
150	1/8	16.9%	62.38	857.6	53,497	4,338	57	$1,177	$674.57	1.74	332	1.18
200	7/64	7.7%	62.26	838	52,173	4,230	56	$1,148	$1,795.89	0.64	332	1.18
250	7/64	4.9%	76.76	820.7	62,995	5,108	67	$1,386	$1,795.89	0.77	409	1.46
300	7/64	1.0%	91.26	805	73,462	5,957	79	$1,616	$1,795.89	0.90	486	1.73
400	5/64	0.6%	61.35	777	47,672	3,865	51	$1,049	$1,795.89	0.58	327	1.17
500	5/64	0.5%	76.15	751.9	57,257	4,643	61	$1,259	$2,038.53	0.62	406	1.45
600	3/32	2.2%	130.96	728.8	95,444	7,739	102	$2,099	$2,038.53	1.03	698	2.49
			Weighted Average Values > 30 psi:	**878.7**		**3,868**	**51**	**$1,049**	**$853.21**	**1.23**	**289**	**1.03**

Table 19: Steam Trap Strainer Installation – Per Unit Energy Savings, Energy Cost Savings, Cost Effectiveness, and Water Savings Results – Alterations

Gauge Pressure (psig)	Orifice Diameter (inch)	Market Share	Open Trap Steam Loss [W] (lb/hr-trap)	Specific Enthalpy Change Fluid to Gas [hfg] (Btu/lb)	Eloss, Open Trap Energy Loss, Btu/hr-trap	Annual Open Trap Energy Loss [Eloss] (Btu/hr-trap)	Annual Energy Savings [ES] (therms/ yr- trap)	15-Year Present Valued Cost Savings [ECS] (2023 PV$/ trap)	15-year Incremental Cost (2023 PV$)	Benefit -to- Cost Ratio	Annual Water Saved (gallons/ yr-trap)	Annual Embedded Electricity Savings (kWh/yr-trap)
15	3/16	-	25.31	945.7	23,936	1,941	26	$526	-	-	135	0.48
30	3/16	9.7%	38.09	929.1	35,392	2,870	38	$778	$774.78	1.00	203	0.72
45	5/32	10.7%	35.33	915.9	32,359	2,624	35	$712	$728.56	0.98	188	0.67
60	5/32	20.6%	44.21	904.9	40,003	3,244	43	$880	$700.04	1.26	235	0.84
80	5/32	8.7%	56.04	892.2	50,002	4,054	54	$1,100	$720.16	1.53	299	1.06
100	5/32	7.9%	67.88	881	59,801	4,849	64	$1,315	$720.16	1.83	362	1.29
125	1/8	8.6%	52.91	868.7	45,964	3,727	49	$1,011	$720.16	1.40	282	1.00
150	1/8	16.9%	62.38	857.6	53,497	4,338	57	$1,177	$749.57	1.57	332	1.18
200	7/64	7.7%	62.26	838	52,173	4,230	56	$1,148	$1,870.89	0.61	332	1.18
250	7/64	4.9%	76.76	820.7	62,995	5,108	67	$1,386	$1,870.89	0.74	409	1.46
300	7/64	1.0%	91.26	805	73,462	5,957	79	$1,616	$1,870.89	0.86	486	1.73
400	5/64	0.6%	61.35	777	47,672	3,865	51	$1,049	$1,870.89	0.56	327	1.17
500	5/64	0.5%	76.15	751.9	57,257	4,643	61	$1,259	$2,113.53	0.60	406	1.45
600	3/32	2.2%	130.96	728.8	95,444	7,739	102	$2,099	$2,113.53	0.99	698	2.49
			Weighted Average Values > 30 psi:	**878.7**		**3,868**	**51**	**$1,049**	**$928.21**	**1.13**	**289**	**1.03**

5. Cost and Cost Effectiveness

5.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 4.2. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). In this case, the period of analysis used is 15 years. The TDV cost impacts are presented in 2023 present value dollars and represent the energy cost savings realized over 15 years.

The present valued energy cost savings were calculated using the 2022 TDV value of PV$22.60/therm, or a levelized value of $1.89/therm. This value was then multiplied by an industrial cost TDV modifier, of 0.91. This discounted rate was developed by the Statewide CASE Team using a ratio of industrial to commercial gas rates for the California 2020-2030 baseline energy demand forecast RATES Form 2.3 (California Energy Commission 2019). The final TDV value used is PV$20.55/therm, or a levelized value of $1.72/therm.

The proposed code change applies to new construction, additions, and alterations. The energy cost savings for additions and alterations are expected to be the same as the energy cost savings for new construction.

5.2 Energy Cost Savings Results

Weighted average per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 15-year period of analysis are presented in 2023 dollars in Table 20 and Table 21, while Appendix G contains the nominal analysis.

Table 20: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Steam Trap – New Construction and Additions

Measure	Climate Zone	15-Year TDV Electricity Cost Savings (2023 PV$)	15-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 15-Year TDV Energy Cost Savings (2023 PV$)
Steam Trap Monitoring	ALL	N/A	$3,147	$3,147
Steam Trap Strainer Installation	ALL	N/A	$1,049	$1,049

Table 21: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Steam Trap – Alterations

Measure	Climate Zone	15-Year TDV Electricity Cost Savings (2023 PV$)	15 Year TDV Natural Gas Cost Savings (2023 PV$)	Total 15-Year TDV Energy Cost Savings (2023 PV$)
Steam Trap Monitoring	ALL	N/A	$3,147	$3,147
Steam Trap Strainer Installation	ALL	N/A	$1,049	$1,049

5.3 Incremental First Cost

For steam trap monitoring, the baseline scenario is assumed to be a steam trap without FDD. To implement the measure, a fault detection sensor and labor to install the sensor are required for each sensor, and a communications gateway is required to ensure that all sensors can communicate with the central monitoring system. See Table 22 for the first costs of the FDD system. These costs are expected to be the same for both new construction, additions and alterations on a per-steam trap basis.

Table 22: Steam Trap Monitoring - 2023 PV First Costs – Per Steam Trap – New Construction, Additions and Alterations

Cost Element	Cost (2023 PV$)	Year Cost is Incurred
Sensor	$956.21	0
Sensor Installation Labor	$95.62	0
Gateway ($2,500, one per 30 sensors)	$83.33	0
Gateway Installation Labor ($200, one per 30 Sensor)	$6.67	0
Building Permit (Permit per Sensor)	$191.24	0
Manual Trap Assessment Savings (per Trap)	$(23.57)	0
Central Monitoring Platform (per Sensor)	$23.57	0
Total Incremental First Cost	**$1,333.07**	

The costs were developed based on feedback from stakeholder outreach. Seven stakeholders provided cost estimates for the components of automatic monitoring systems. Prices ranged from $300/trap-year to upfront costs of $1800/trap. Multiple fault detection sensors can communicate with one gateway. The minimum viable size was determined to be a thirty-sensor system when accounting for the cost of the gateway, and the associated installation and central monitoring platform costs. Twenty five percent of sensors would be installed in year zero, with the remaining sensor installations occurring in years one through three, the average costs are reflected in the first costs. Permit costs would be incurred for each sensor. Manufacturer's primarily sell wireless sensors which communicate with the gateway, and do not require additional conduit and wiring for power. There is a financial benefit from removing the cost of manual steam trap condition assessment when implementing the measure.

For steam trap strainer installation, the baseline scenario is assumed to be a steam trap without an upstream strainer and blow-off valve assembly. To implement the measure, a strainer and blow-off valve assembly are required. This measure applies to new construction, additions and alterations, and the labor for implementation is included. See Table 23 for the assumptions made to develop strainer and steam trap costs for the strainer cost model. The estimated steam trap costs included are independent of strainer costs

See Table 24 for the first costs of the steam trap strainer installation measure. These costs are expected to be the same for both new construction and additions on a per-trap basis.

Table 23: Representative Strainer and Steam Trap Cost Estimates for the Strainer Cost Model

Inlet Pressure [psig]	Working Temperature [F]	Standard Orifice Diameter (inches)	Corres-ponding steam pipe diameter (in)	Conservative Upsized Condensate Pipe Diameter (in)	Strainer Pressure Rating	Population of Steam Trap Market at Inlet Pressure [%]	Stand-alone strainer cost	Steam Trap Mass Flow [lbs/hr]	Steam Trap Est. Cost
30	274	3/16	0.75	1	150	9.70%	$445	38	$330
45	292	5/32	0.75	1	150	10.70%	$445	35	$385
60	307	5/32	0.5	0.75	150	20.60%	$420	44	$365
80	324	5/32	0.75	1	150	8.70%	$445	56	$395
100	338	5/32	0.75	1	150	7.90%	$445	68	$395
125	353	1/8	0.75	1	150	8.60%	$445	53	$395
150	366	1/8	0.75	1	150	16.90%	$445	62	$360
200	388	7/64	0.5	0.75	300	7.70%	$1,082	62	$400
250	406	7/64	0.5	0.75	300	4.90%	$1,082	77	$400
300	422	7/64	0.5	0.75	300	1.00%	$1,082	91	$400
400	448	5/64	0.5	0.75	300	0.60%	$1,082	61	$400
500	470	5/64	0.5	0.75	400	0.50%	$1,239	76	$450
600	489	3/32	0.5	0.75	400	2.20%	$1,239	131	$450
						Weighted Averages	$551.74	55	$377.73

Code compliance for steam trap strainer installation is achieved through either the installation of a strainer and blow-off valve within 3 feet of a downstream steam trap or through the installation of a steam trap with integral strainer and blow-off valve. The cost modeling presented in the Draft CASE Report is based on a stand-alone strainer and blow-off valve configuration. It is believed that the integral strainer and blow-off valve configuration would be substantially less costly than the stand-alone configuration. Initial estimates indicate that the incremental cost of an integral strainer and blow off would be $50-$100. In this configuration the B/C Ratio for all steam pressures would be larger than five to one. The Statewide CASE Team will be looking at this alternative option in more detail and welcomes comments on the feasibility and cost-effectiveness of integral strainers as a method of protecting steam traps and extending the useful life of steam traps.

The Statewide CASE Team is investigating and specifically seeking additional data sources to determine a) the current prevalence of steam traps installed with integral strainers and b) the incremental cost of a steam trap with an integral strainer compared to a steam trap not equipped with an integral strainer and blow-off valve. Pending acquisition of integral strainer cost data, the cost modeling may be updated for the final CASE Report. This consideration of integral strainer cost and market share and consequent updates to cost effectiveness have the potential to result in the code change proposal applying to systems operating at 15 psig and higher rather than 30 psig and higher.

Table 24: Steam Trap Strainer Installation - 2023 PV First Costs – Per Strainer – New Construction/Additions

Cost Element	Cost (2023 PV$)	Year Cost is Incurred
Strainer	$551.74	0
Installation Labor	$75.00	0
Total Incremental First Cost	**$626.74**	

Table 25 represents the first costs of the quality installation measure for alterations. The labor is expected to be greater when breaking pipe to install a strainer assembly upstream of a steam trap where there was previously no existing strainer.

Table 25: Steam Trap Strainer Installation - 2023 PV First Costs – Per Strainer – Alterations

Cost Element	Cost (2023 PV$)	Year Cost is Incurred
Strainer	$551.74	0
Installation Labor	$150.00	0
Total Incremental First Cost	**$701.74**	

Based on data from available cost databases and stakeholder interviews, equipment and labor cost estimates were developed. Labor is estimated to be one-half hour for new construction and additions, and one hour for alterations. Pricing for strainers ranges from the relatively inexpensive to the very expensive, based on material and application. The costs presented in Table 25 present the most reasonable values, as determined by multiple stakeholder interviews.

5.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 15-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2022 TDV. The present value of maintenance costs that occurs in the nth year is calculated as follows:

$$\text{Present Value of Maintenance Cost} = \text{Maintenance Cost} \times \left\lfloor \frac{1}{1+\mathrm{d}} \right\rfloor^{\mathrm{n}}$$

For steam trap monitoring, the anticipated useful life of the sensor and gateway is ten years, based on stakeholder feedback. The remaining seventy five percent of the minimum viable system size's sensors would be installed in years one through three, and all sensors would be replaced again over a four-year period starting in year 10. Replacement for the gateway is expected in year ten of the lifecycle cost analysis. Sensor and gateway replacement can be performed by in-house maintenance staff. Additionally, the sensor utilizes a battery to power its communication with the central monitoring system. The useful life of the battery is three years based on stakeholder feedback. Replacements are made in years three through 15 in the lifecycle cost analysis. Battery replacement can be made by in-house maintenance staff. The cost of the monitoring service, and the cost savings from reducing the need for manual inspection would be accrued starting in year one and extending to year 15.

Savings that result from timely awareness of steam trap failure are dependent on the operational behavior of the facility installing the monitoring system. It is not the purview of Title 24, Part 6 to regulate operational behavior, however timely repair of steam traps upon failure is necessary to deliver energy savings. Results of the incremental maintenance cost analysis for steam trap monitoring are presented in Table 26.

Table 26: Steam Trap Monitoring - 2023 PV Incremental Maintenance and Replacement Costs – Per Steam Trap – New Construction/Additions/Alterations

Cost Element	Cost (2023 PV$)	Year Cost is Incurred
Sensor	$711.51	10

Sensor Installation Labor	$71.15	10
Gateway ($2,500, one per 30 sensors)	$62.01	10
Gateway Installation Labor	$4.96	10
Building Permit (Permit per Sensor)	$142.30	10
Manual Trap Assessment Savings (per Trap)	$(227.73)	1-15
Central Monitoring Platform Service ($187/ea)	$227.73	1-15
Battery ($100)	$322.92	3, 6, 9, 12, 15
Total Incremental Maintenance and Equipment Cost	**$1,314.85**	

For steam trap strainer installation, the anticipated useful life of the strainer is 7.5 years. A replacement of the strainer, and associated labor, is expected during the lifecycle cost analysis. Additionally, the strainer requires bi-annual maintenance as a best practice to clear the strainer of debris. This is estimated to occur during each year of the lifecycle cost analysis. Maintenance can be completed by in-house maintenance staff. Persistence of savings from steam trap strainer installation derive from improving the useful life of the associated steam trap, and bi-annual maintenance is necessary to ensure proper strainer operation. Steam trap strainer installation also benefits from one fewer steam trap replacements during the lifecycle, and this secondary benefit is accounted for in the incremental maintenance and replacement cost analysis. Maintenance and replacement costs are the same for new construction, additions and alterations. Results from the incremental maintenance cost analysis for steam trap strainer installation are presented in Table 27.

Table 27: Steam Trap Strainer Installation - 2023 PV Incremental Maintenance and Replacement Costs – Per Strainer– New Construction/Additions/Alterations

Cost Element	Cost (2023 PV$)	Year Cost is Incurred
Strainer	$448.62	7
Strainer Labor	$60.98	7
Steam Trap Replacement (4 yr interval)	($898.71)	4, 8, 12
Steam Trap Replacement Labor (4 yr interval)	($178.45)	4, 8, 12
Steam Trap Replacement (6yr interval)	$581.27	6, 12
Steam Trap Replacement Labor (6 yr interval)	$115.41	6, 12
Maintenance ($8.75/ea)	$97.34	1-15
Total Incremental Maintenance and Equipment Cost	**$226.47**	

5.5 Cost Effectiveness

This measure proposes a mandatory requirement. As such, a cost analysis is required to demonstrate that the measure is cost effective over the 15-year period of analysis.

The Energy Commission establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 15-year period of analysis were included. The TDV energy cost savings from natural gas savings were also included in the evaluation.

Design costs were not included nor were the incremental costs of code compliance verification.

According to the Energy Commission's definitions, a measure is cost effective if the benefit-to-cost (B/C) ratio is greater than 1.0. The B/C ratio is calculated by dividing the cost benefits realized over 15 years by the total incremental costs, which includes maintenance costs for 15 years. The B/C ratio was calculated using 2023 PV costs and cost savings.

Results of the per-unit cost-effectiveness analyses are presented in Table 28 and Table 29 for new construction and alterations, respectively. For steam trap monitoring, the proposed measure saves money over the 15-year period of analysis relative to the existing conditions. The proposed code change is cost effective for new construction, additions and alterations. For strainer installation, the proposed measure saves money over the 15-year period of analysis relative to the existing conditions, and is cost effective for new construction, additions and alterations.

While the benefit-to-cost ratio may appear to be on the fine edge of cost effectiveness for both steam trap monitoring and strainer installation, the pressure bins were selected to maximize energy savings opportunity. There is an inherent trade-off made in the analysis between improving the cost effectiveness, and the overall statewide energy savings that would be claimed. If there were a desire to improve the cost-effectiveness of the proposed measures, the minimum steam inlet pressure would need to increase, reducing the overall market share of steam traps subject to the proposed measure.

As discussed in Section 5.3, the Statewide CASE Team believes that the integral strainer and blow-off valve configuration would be substantially less costly than the stand-alone configuration. With this configuration, the B/C ratio for all steam pressures could increase above 5.0. The Statewide CASE Team will be investigating this alternative option in more detail and welcomes comments on the feasibility and cost effectiveness of integral strainers as a method of protecting steam traps and extending the useful life of steam traps. Pending acquisition of integral strainer cost data, the cost modeling and B/C ratios may be updated for the Final CASE Report. This consideration of integral strainer cost and market share and consequent updates to cost effectiveness have the potential to result in the code change proposal applying to systems operating at 15 psig and higher rather than 30 psig and higher.

Table 28: 15-Year Cost-Effectiveness Summary Per Steam Trap – New Construction/Additions

Measure	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
Steam Trap Monitoring	$3,147	$2,648	1.19
Steam Trap Strainer Installation	$1,049	$853	1.23

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. PV maintenance cost savings are included if PV of proposed maintenance costs is less than PV of current maintenance costs.

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

Table 29: 15-Year Cost-Effectiveness Summary Per Unit – Alterations

Measure	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
Steam Trap Monitoring	$3,147	$2,648	1.19
Steam Trap Strainer Installation	$1,049	$928	1.13

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Present value maintenance cost savings are included if PV of proposed maintenance costs is less than PV of current maintenance costs.

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

6. First-Year Statewide Impacts

6.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction and additions by estimating the size of the industrial steam-using market in California, adjusting for annual steam trap failure rates, and leakage as a percent of usage. The per-unit savings values were used to determine the number of steam traps impacted by this steam leakage value. The statewide savings calculation for 2023 is presented in Appendix A as are the Statewide CASE Team's assumptions to calculate the savings.

The savings for alterations uses a similar methodology.

The first-year energy impacts represent the first-year annual savings from all industrial steam users that had estimated new construction or additions completed in 2023. While the total number of sites is relatively low, the impacts of this measure are high due to the heavy usage of natural gas by these end users. The 15-year energy cost savings represent the energy cost savings over the entire 15-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

The Statewide CASE Team identified from stakeholder outreach that there is limited new construction growth in the state for process steam systems, and that de-industrialization and de-carbonization present substantial barriers to realizing new construction cost and energy savings.

Table 30 presents first-year statewide savings from new construction, additions, and alterations for steam trap monitoring.

Table 30: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions for Steam Trap Monitoring

Construction Type	First-Year Electricity Savings (GWh)[b]	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (million therms)	15-Year Present Valued Energy Cost Savings (2023 PV$ million)
New Construction/Additions	0.001	NA	0.061	$1.25
Alterations	0.025	NA	1.219	$25.05
TOTAL	**0.026**	**NA**	**1.280**	**$26.30**

a. First-year savings from all alterations completed statewide in 2023.

b. First-year electricity savings are embedded electricity savings.

Stakeholder interviews identified that strainer installation upstream of steam traps is considered an industry best practice and is substantially a standard practice for new construction. To a lesser extent, strainers are frequently found upstream of existing steam trap installations, so this statewide analysis accounts for reduced cost and energy savings as a result of making a standard practice mandatory.

Table 30 presents first-year statewide savings from new construction, additions, and alterations for steam trap strainer installation.

Table 31: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions for Steam Trap Strainer Installation

Construction Type	First-Year Electricity Savings (GWh)[b]	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (million therms)	15-Year Present Valued Energy Cost Savings (2023 V$ million)
New Construction/Additions	0.000	NA	0.004	$0.08
Alterations	0.005	NA	0.244	$5.01
TOTAL	**0.005**	**NA**	**0.248**	**$5.09**

a. First-year savings from all alterations completed statewide in 2023.

b. First-year electricity savings are embedded electricity savings.

6.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion. Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42). See Appendix C for additional details on the methodology used to calculate GHG emissions. In short, this analysis assumes an average electricity emission factors of 240.04 metric tons CO2e per GWh based on the average emission factors for the CACX EGrid Subregion.

Table 32 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 8,341 metric tons of carbon dioxide equivalents (metric tons CO2e) would be avoided.

Table 32: First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (million therms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[a,b] (Metric Tons CO2e)
Automatic Steam Trap Monitoring	0.026	6.293	1.280	6,981.6	6,987.9
Steam Trap Strainer Installation	0.005	1.219	0.248	1,352.0	1,353.2
TOTAL	**0.031**	**7.511**	**1.528**	**8,333.6**	**8,341.2**

a. First-year savings from all buildings completed statewide in 2023.

b. Assumes the following emission factors: 240.4 MTCO2e/GWh and 5,454.4 MTCO2e/million therms.

6.3 Statewide Water Use Impacts

The proposed code change would result in water savings. The calculation assumes an average latent heat of vaporization for water of 879 Btu per pound-mass. It also assumes that 50 percent of steam lost through failed steam traps is ultimately vented to the atmosphere and the other 50 percent is returned as condensate back to the boiler, this assumption is based on stakeholder estimates from field observations. It was assumed that all water savings occurred outdoors, and the embedded electricity value was 3,565 kWh/million gallons of water. The embedded electricity estimate was derived from a 2015 CPUC study that quantified the embedded electricity savings from IOU programs that save both water and energy (CPUC 2015). See in Appendix B additional information on the embedded electricity savings estimates.

Water and embedded electricity savings per steam trap for FDD are presented in Table 17 and strainer installation are presented in Table 18 and Table 19. Impacts on statewide water use are presented in Table 33. This measure is expected to contribute a 0.0000667 percent annual reduction to statewide annual water consumption.

Table 33: Impacts on Water Use and Embedded Electricity in Water

	On-Site Indoor Water Savings (gallons/yr)	On-Site Outdoor Water Savings (gallons/yr)	Embedded Electricity Savings (kWh/yr)
Per Automatic Steam Trap Monitoring Impacts	NA	867	3.09
Per Strainer Impacts	NA	289	1.03

First-Year Statewide Impacts	NA	8,765,000	31,000

a. Assumes embedded energy factor of 4,848kWh per million gallons of water for indoor use and 3,565 kWh per million gallons of water for outdoor water use (CPUC 2015).

b. First-year savings from all buildings completed statewide in 2023.

6.4 Statewide Material Impacts

The new code requirement would result in the increased use of steel, plastic, aluminum and rubber as no previous requirement for the measure existed. The code proposal requires the use of automatic monitoring equipment and strainer assemblies for steam traps where there previously would have been no existing equipment. Based on stakeholder feedback, Table 34 presents the material impact estimates associated with FDD systems and strainers on a per-unit basis and annually statewide.

Table 34: First-Year Statewide Impacts on Material Use

Material	Impact (I, D, or NC)[a]	Impact on Material Use (pounds/year)	
		Per-Unit Impacts	First-Year[b] Statewide Impacts
Automatic Steam Trap Monitoring System Impacts			
Mercury	NC	N/A	N/A
Lead	NC	N/A	N/A
Copper	NC	N/A	N/A
Steel	I	2	16,714
Plastic	I	1	8,357
Aluminum	I	1	8,357
Rubber	I	0.25	2,089
Strainer Impacts			
Steel	I	2.5	12,138

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

b. First-year savings from all buildings completed statewide in 2023.

6.5 Other Non-Energy Impacts

Potential non-energy impacts which were not quantified in this report include: the possibility for improved steam system reliability by reducing steam water hammer in distribution piping caused by failed steam traps; increased process uptime and product quality due to properly operating steam traps; and potential health and safety benefits from early detection of failed closed steam traps. One potential health and safety related benefit would be the reduced potential for water hammer from early notification of failed closed steam traps. Water hammer may lead to pipe or vessel rupture in steam systems which in the past has periodically caused human injury and even death. The measure would minimally reduce the amount of water treatment required for the make-up feedwater to the steam boiler. As a result, this would reduce the amount of chemicals needed for treatment processes and the associated maintenance required. An additional improvement is outdoor air quality from the reduced utilization of natural gas for steam boiler combustion.

7. Proposed Revisions to Code Language

7.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

7.2 Standards

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

(a) **Rules of Construction.**

1. Where the context requires, the singular includes the plural and the plural includes the singular.
2. The use of "and" in a conjunctive provision means that all elements in the provision must be complied with, or must exist to make the provision applicable. Where compliance with one or more elements suffices, or where existence of one or more elements makes the provision applicable, "or" (rather than "and/or") is used.
3. "Shall" is mandatory and "may" is permissive.

(b) **Definitions.** Terms, phrases, words and their derivatives in Part 6 shall be defined as specified in Section 100.1. Terms, phrases, words and their derivatives not found in Section 100.1 shall be defined as specified in the "Definitions" chapters of Title 24, Parts 1 through 5 of the California Code of Regulations. Where terms, phrases, words and their derivatives are not defined in any of the references above, they shall be defined as specified in *Webster's Third New International Dictionary of the English Language, Unabridged* (1961 edition, through the 2002 addenda), unless the context requires otherwise.

STEAM TRAP OPERATING PRESSURE is the steam pressure entering the steam trap during normal design operating conditions.

Section 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES

Nonresidential, high-rise residential, and hotel/motel buildings shall comply with the applicable requirements of Sections 120.6(a) through 120.6(h).

120.6(h) Mandatory Requirements for Steam Traps. All new construction, all additions, and all steam trap alterations where the installed steam trap operating pressure is greater than 30 psig and the total combined connected boiler input rating is greater than 2 MMBtu/hr shall conform to the following:

1. **Steam Trap Fault Detection.** Steam traps shall be equipped with automatic fault detection sensors that shall communicate their operational state to the central steam trap monitoring system as described in item 120.6(h)2 of this section.

2. Central Steam Trap Monitoring. Steam trap systems shall be equipped with a central steam trap monitoring system that:

A. Provides a status update of all steam trap fault detection sensors at no greater than 1-hour intervals.

B. Automatically transmits an alarm to the facility operator that identifies which steam trap has fault once the system has detected a fault.

3. Steam Trap Strainer Installation. Steam traps shall either:

A. Be equipped with an integral strainer and blow-off valve; or

B. Be installed downstream within 3 feet of a strainer and blow-off valve.

4. Steam Trap System Acceptance. Before an occupancy permit is granted for steam trap systems subject to 120.6(h), the equipment and systems shall be certified as meeting the Acceptance Requirement for Code Compliance, as specified by the Reference Nonresidential Appendix NA7. A Certificate of Acceptance shall be submitted to the enforcement agency that certifies that the equipment and systems meet the acceptance requirements specified in NA7.19.

7.3 Reference Appendices

NA7.19 Steam Trap Fault Detection Acceptance Tests

NA7.19.1 Construction Inspection

Prior to functional testing, steam trap systems must verify and document the following:

(a) Rated capacity (MMBtu/h) of each connected steam boiler and annual operating hours.

(b) Distribution system steam trap arrangement and connected steam line operating pressure subject to 120.6(h) were installed as designed including the presence of monitoring equipment, strainer, and strainer blow-off valve.

(c) Visual confirmation of the central steam trap monitoring system installation, operation and programmed as designed.

(d) Confirm the central steam trap monitoring system displays status of all installed steam trap sensors with a descriptive label or cross-references to a look-up table with location of sensor.

NA7.19.2 Functional Testing

For steam systems with up to seven (7) steam traps required to have fault detection in accordance with Section 120.6(h), all steam traps shall be tested. For steam systems with more than seven (7) steam traps; sampling shall include a minimum of 1 steam trap for each group of up to 7 additional steam traps. If the first steam trap in the sample group passes the acceptance test, the remaining steam traps in the sample group also pass. If the first steam trap in a sample group fails, the rest of the steam traps in that group must be tested. If any tested steam trap fault detection sensor fails it shall be repaired, replaced or adjusted until it passes the test.

For each fault detection sensor, test the following:

Step 1: Identify the status of the steam trap and note if the steam line is operational or non-operational at the time of the functional test.

Step 2: Confirm that central steam trap monitoring system is receiving a signal that reflects the status of the steam trap.

Step 3: Generate a fault at the steam trap sensor for each tested steam trap.

Step 4: Verify that the central steam trap monitoring system detects the fault and reports the fault detection to the operator.

Step 5: Reconnect steam trap sensor and verify the fault detection sensor is communicating with the central steam trap monitoring system.

Step 6: Verify that central steam trap monitoring system does not report a fault.

7.4 ACM Reference Manual

There are no proposed changes to the ACM Reference Manual.

7.5 Compliance Manuals

Chapters 10 and 13 as well as the supporting Appendices (A) of the Nonresidential Compliance Manual would need to be revised. A new Section, 10.12 “Steam Traps”, would need to be created. This section would include subsections that discuss in detail the proposed measure code overview, the mandatory measure requirements, new construction and additions and alteration requirements. This section should include several examples to illustrate compliance for variety of systems. Additionally, a process flow diagram of the compliance channel(s) and market actors would provide clarity to market actors not previously subject to energy code compliance. Chapter 13 shall make mention of a new compliance process for covered processes in Section 13.4.4 and update table 13-1.Appendix A shall be updated to include the new compliance documents discussed in Section 7.6 below.

7.6 Compliance Documents

Compliance documents NRCC-PRC-E, NRCI-PRC-01-E would need to be revised; compliance document NRCA-PRC-17-F would need to be created.

Compliance document NRCC-PRC-E would need to be revised to include Section 120.6(h) of the building energy code. This document would be completed by the design team and submitted with the building department plan review for new construction and additions of steam distribution systems subject to Section 120.6(h).

Compliance document NRCI-PRC-01-E would need to be revised to include Section 120.6(h) of the building energy code. This document would be completed by the installer and submitted to the building department upon completion of the installation of all replacement steam traps subject to Section 120.6(h).

New compliance document NRCA-PRC-17-F would need to be added to Appendix A Compliance Documents. The new document certifies that the FDD systems and steam trap strainer installations meet the acceptance requirements specified in NA7.19.

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Appendix A: Statewide Savings Methodology

This appendix is a placeholder to provide additional information about the statewide savings methodology in the Final CASE Report.

Appendix B: Embedded Electricity in Water Methodology

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

These embedded electricity values were derived from research conducted for CPUC Rulemaking 13-12-011. The CPUC study aimed to quantify the embedded electricity savings associated with IOU incentive programs that result in water savings, and the findings represent the most up-to-date research by the CPUC on embedded energy in water throughout California (California Public Utilities Commission 2015a, California Public Utilities Commission (CPUC) 2015b). The CPUC analysis was limited to evaluating the embedded electricity in water and does not include embedded natural gas in water. For this reason, this CASE Report does not include estimates of embedded natural gas savings associated with water reductions, though the embedded electricity values can be assumed to have the same associated emissions factors as grid-demanded electricity in general.

The specific CPUC embedded electricity values used in the CASE analysis are shown in Table 35. These values represent the average energy intensity by hydrologic region, which are based on the historical supply mix for each region regardless of who supplied the electricity (IOU-supplied and non-IOU- supplied electricity). The CPUC calculated the energy intensity of marginal supply but recommended using the average IOU and non-IOU energy intensity to estimate total statewide average embedded electricity of water use in California.

Table 35: Embedded Electricity in Water by California Department of Water Resources Hydrologic Region (kWh Per Acre Foot (AF))

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

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

Source: (California Public Utilities Commission (CPUC) 2015b).

The Statewide CASE Team used CPUC's indoor and outdoor embedded electricity estimates by hydrologic region (presented in Table 35) and population data by hydrologic region from the U.S. Census Bureau (U.S. Census Bureau, Population Division 2014) to calculate the statewide population-weighted average indoor and outdoor embedded electricity values that were used in the CASE analysis (see Table 36). The energy intensity values presented in Table 35 were converted from kWh per acre foot to kWh per million gallons to harmonize with the units used in the CASE analysis. There are 3.07acre feet per million gallons.

Table 36: Statewide Population-Weighted Average Embedded Electricity in Water

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

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

Appendix C: Environmental Impacts Methodology

Greenhouse Gas (GHG) Emissions Factors

As directed by Energy Commission staff, GHG emissions were calculated making use of the average emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion (United States Environmental Protection Agency 2018). This ensures consistency between state and federal estimations of potential environmental impacts. The electricity emissions factor calculated from the eGRID data is 240.4 metric tons CO2e per GWh. The Summary Table from eGrid 2016 reports an average emission rate of 529.9 pounds CO2e/MWh for the WECC CAMX subregion. This value was converted to metric tons/GWh.

Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in Chapter 1.4 of the U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42) (United States Environmental Protection Agency 1995). The U.S. EPA's estimates of GHG pollutants that are emitted during combustion of one million standard cubic feet of natural gas are: 120,000 pounds of CO_2 (Carbon Dioxide), 0.64 pounds of N_2O (Nitrous Oxide) and 2.3 pounds of CH_4 (Methane). The emission value for N_2O assumed that low NOx burners are used in accordance with California air pollution control requirements. The carbon equivalent values of N_2O and CH_4 were calculated by multiplying by the global warming potentials (GWP) that the California Air Resources Board used for the 2000-2016 GHG emission inventory, which are consistent with the 100-year GWPs that the Intergovernmental Panel on Climate Change used in the fourth assessment report (AR4). The GWP for N_2O and CH_4 are 298 and 25, respectively. Using a nominal value of 1,000 Btu per standard cubic foot of natural gas, the carbon equivalent emission factor for natural gas consumption is 5,454.4 metric tons per million therms.

GHG Emissions Monetization Methodology

The 2022 TDV energy cost factors used in the lifecycle cost-effectiveness analysis include the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs). As of the Draft CASE Report's date of publication, the Energy Commission has not released the final TDV factors. The Final CASE Report will show the monetary value of avoided GHG emissions using assumptions that align with those used for the 2022 TDV factors.

Water Use and Water Quality Impacts Methodology

There are no impacts to water quality or water use.

Appendix D: California Building Energy Code Compliance (CBECC) Software Specification

There are no recommended revisions to the compliance software as a result of this code change proposal.

Appendix E: Impacts of Compliance Process on Market Actors

This appendix discusses how the recommended compliance process, which is described in Section 2.5, could impact various market actors. Table 37 identifies the market actors who would play a role in complying with the proposed change, the tasks for which they would be responsible, their objectives in completing the tasks, how the proposed code change could impact their existing work flow, and ways negative impacts could be mitigated. The information contained in Table 37 is a summary of key feedback the Statewide CASE Team received when speaking to market actors about the compliance implications of the proposed code changes. Appendix F summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the code change proposal, including gathering information on the compliance process.

Table 37: Roles of Market Actors in the Proposed Compliance Process

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Energy Commission	• Develop new compliance documents as needed. • Maintain compliance documentation (including Nonresidential Compliance Manual and necessary document(s)).	Provide easily accessible compliance documentation requirements to System Designer, Plans Examiner, Installer and other Field Technician.	• Would need to revise documentation to accommodate this code addition, forms to be revised include NRCC-PRC-E & NRCI-PRC-01-E. • Would need to create form NRCA-PRC-17-F. • Would need to revise Sections 10 and 13 of Nonresidential Compliance Manual	Ensure compliance documents clearly identify individual requirements so that plans examiners, Installers and other Field Technicians can certify as needed.
System Designer	• Identify relevant requirements pertaining to new mandatory covered process- identify applicability of 120.6(h). • Include in relevant specification in design documents. • Complete Certificate of Compliance document for permit application including NRCC-PRC-E. • Coordinates with Installer or other Field Technician, as necessary.	• Quickly and easily determine if steam system is subject to code requirements based on scope. • Streamline coordination with plans examiner, installer, Field Technician. • Quickly and accurately complete compliance documents. • Clearly communicate system design requirements to installer.	• New Construction and Additions would result in increased design cost and timeline. • New Construction and Additions would require understanding of energy code impact on steam systems which has not previously been impacted.	• Steam system design firms should be provided training on the energy code adoption. • Steam system design firms should be provided training on compliance requirements and compliance documentation.

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Plans Examiner	• Checks submitted building design plans are in compliance with Section 120.6(h) of the CA building energy code. • Reviews and provides NRCC-PRC-E.	• Quickly and easily provide review and determine if proposed system specifications are in compliance. • Quickly review provided manufacturer certification document and matches design specified equipment. • Quickly and easily provide correction comments to resolve issues.	• Plans examiner is not accustomed to reviewing steam system components. • Some increase in plans review timeline. • Delays could result in impacts to construction and installation timeline.	Provide education and training to local building department plans examiners to familiarize with the new code language of 120.6(h).
Facility Manager	Oversee alterations subject to 120.6(h) effectively meet compliance requirements.	Quickly and effectively replace failed steam traps while complying with Section 120.6(h).	• Time commitment to support construction and functional acceptance test requirements. • Delays in the installation of replacement steam traps could have adverse effects on life safety, process implications and/or energy savings realization.	• Provide education that steam trap systems are potentially subject to 120.6(h). • Provide education for streamlined compliance.

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Installer	• Review new design requirements components and equipment specifications subject to Section 120.6(h). • Install equipment as specified in the approved design documents. • Completes and submits NRCA-PRC-01-E and NRCA-PRC-17-F for New Construction and Additions as needed per Section NA7.16. • For Alterations, identify relevant requirements pertaining to new mandatory covered process- identify applicability of 120.6(h). • For Alterations (steam trap replacements) completes and submits NRCI-PRC-01-E.	• Quickly and easily determine if steam system is subject to code requirements based on scope. • Streamline coordination with designer, facility manager or Field Technician (as needed). • Quickly and accurately review compliance documents. • Quickly review provided manufacturer certification document and matches design specified equipment. • Quickly and accurately complete and submit compliance documents.	• New Construction and Additions would require additional review of design plans. • Alterations would require understanding of equipment and compliance requirements. • Alterations would result in significantly increased timeline for steam trap replacement. • Installer could act as new construction or addition compliance acceptance market actor performing Field Technician related certification process.	• Steam system installer should be provided training on the energy code adoption. • Steam system installers should be provided training on compliance requirements and associated compliance documentation. • Self-certify as the Field Technician, certification would expedite facility permitting process.
Field Technician	• Complete NA7.16 compliance tests for new construction and additions. • Submit NRCA-PRC-01-E and NRCA-PRC-17-F as required.	Coordinate with installer and/or facility manager to conduct compliance test and address any determined issues.	Would require additional training to conduct compliance tests.	Field Technician could be the installer to expedite acceptance requirements.

Appendix F: Summary of Stakeholder Engagement

Collaborating with stakeholders that might be impacted by proposed changes is a critical aspect of the Statewide CASE Team's efforts. The Statewide CASE Team aims to work with interested parties to identify and address issues associated with the proposed code changes so that the proposals presented to the Energy Commission in this Draft CASE Report are generally supported. Public stakeholders provide valuable feedback on draft analyses and help identify and address challenges to adoption including cost effectiveness; market barriers; technical barriers; compliance and enforcement challenges; or potential impacts on human health or the environment. Some stakeholders also provide data that the Statewide CASE Team uses to support analyses.

This appendix summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the recommendations presented in this report.

Utility-Sponsored Stakeholder Meetings

Utility-sponsored stakeholder meetings provide an opportunity to learn about the Statewide CASE Team's role in the advocacy effort and to hear about specific code change proposals that the Statewide CASE Team is pursuing for the 2022 code cycle. The goal of stakeholder meetings is to solicit input on proposals from stakeholders early enough to ensure the proposals and the supporting analyses are vetted and have as few outstanding issues as possible. To provide transparency in what the Statewide CASE Team is considering for code change proposals, during these meetings the Statewide CASE Team asks for feedback on:

- Proposed code changes
- Draft code language
- Draft assumptions and results for analyses
- Data to support assumptions
- Compliance and enforcement, and
- Technical and market feasibility

The Statewide CASE Team hosted one stakeholder meetings for (Automatic) steam trap monitoring via webinar. Please see below for dates and links to event pages on Title24Stakeholders.com. Materials from each meeting such as slide presentations, proposal summaries with code language, and meeting notes, are included in the bibliography section of this report.

Table 38: Stakeholder Presentation(s) Summary

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
First Round of Covered Processes (Part 2) Utility-Sponsored Stakeholder Meeting	Thursday, November 7, 2019	https://title24stakeholders.com/event/nonresidential-covered-processes-utility-sponsored-stakeholder-meeting/

The first round of utility-sponsored stakeholder meetings occurred from September to November 2019 and were important for providing transparency and an early forum for stakeholders to offer feedback on measures being pursued by the Statewide CASE Team. The objectives of the first round of stakeholder meetings were to solicit input on the scope of the 2022 code cycle proposals; request data and feedback on the specific approaches, assumptions, and methodologies for the energy impacts and cost-effectiveness analyses; and understand potential technical and market barriers. The Statewide CASE Team also presented initial draft code language for stakeholders to review.

The second round of utility-sponsored stakeholder meetings were postponed in favor of additional time spent in focused stakeholder outreach for the Statewide CASE team.

Utility-sponsored stakeholder meetings were open to the public. For each stakeholder meeting, two promotional emails were distributed from info@title24stakeholders.com One email was sent to the entire Title 24 Stakeholders listserv, totaling over 1,900 individuals, and a second email was sent to a targeted list of individuals on the listserv depending on their subscription preferences. The Title 24 Stakeholders' website listserv is an opt-in service and includes individuals from a wide variety of industries and trades, including manufacturers, advocacy groups, local government, and building and energy professionals. Each meeting was posted on the Title 24 Stakeholders' LinkedIn page[7] (and cross-promoted on the Energy Commission LinkedIn page) two weeks before each meeting to reach out to individuals and larger organizations and channels outside of the listserv. The Statewide CASE Team conducted extensive personal outreach to stakeholders identified in initial work plans who had not yet opted into the listserv. Exported webinar meeting data captured attendance numbers and individual comments,

[7] Title 24 Stakeholders' LinkedIn page can be found here: https://www.linkedin.com/showcase/title-24-stakeholders/

and recorded outcomes of live attendee polls to evaluate stakeholder participation and support.

Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email and phone with numerous stakeholders when developing this report. Table 27 below details conducted stakeholder outreach which was essential to the development of the code proposal as described in the preceding sections of the CASE Report. It should be noted that this is not exhaustive list of stakeholders who were contacted. Many additional stakeholders from a variety of market perspectives were contacted with which only limited or no response was collected.

Table 39: Targeted Stakeholder Outreach Summary

Market Actor Type	Company Type	Source
Subject Matter Expert (1)	Manual Steam Trap Assessment Company (1)	(S. (1) 2019)
Subject Matter Expert (2)	Manual Steam Trap Assessment Company (1)	(S. (2) 2019)
California End User (1)	California Steam End User Company (1)	(E. (1) 2019)
Design Engineer (1)	Steam System Design Engineer Company (1)	(D. (1) 2019)
Automatic Steam Trap Monitoring (1)	Steam Trap and Automatic Steam Trap Monitoring Company (1)	(A. (1), 10252019 - ASTM (1) – ST_ASTM Manufacturer (1) 2019)
Automatic Steam Trap Monitoring (2)	Automatic Steam Trap Monitoring Company (2)	(A. (2), 10292019 - ASTM (2) –ASTM Manufacturer (2) 2019)
Subject Matter Expert (3)	Manual Steam Trap Assessment Company (3)	(S. (3) 2019)
Automatic Steam Trap Monitoring (3)	Automatic Steam Trap Monitoring Company (3)	(A. (3) 2019)
Automatic Steam Trap Monitoring (4)	Steam Trap and Automatic Steam Trap Monitoring Company (4)	(A. (4) 2019)
Subject Matter Expert (4)	Distributor, Vendor, Designer (1)	(S. (4) 2019)
Automatic Steam Trap Monitoring (1)	Steam Trap and Automatic Steam Trap Monitoring Company (1)	(A. (1), 02112020 - ASTM (1) – ST_ASTM Manufacturer (1) 2020)
Automatic Steam Trap Monitoring (2)	Automatic Steam Trap Monitoring Company (2)	(A. (2), 02112020 - ASTM (2) –ASTM

		Manufacturer (2) 2020)

Appendix G: Nominal Energy Cost Savings

This appendix will be included for the Final CASE Report.

In Section 5.2, the energy cost savings of the proposed code changes over the 15-year period of analysis are presented in 2023 present value dollars.

This appendix presents energy cost savings in nominal dollars. Energy costs are escalating as in the TDV analysis but the time value of money is not included so the results are not discounted.