Codes and Standards Enhancement (CASE) Initiative 2022 California Energy Code

Steam Trap Monitoring

2022-NR-COV-PROC3-F **|** Nonresidential **|** October 2020 FINAL CASE REPORT

Prepared by AESC, Inc., Energy Solutions

Please submit comments to info@title24stakeholders.com.

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Executive Summary

This document presents recommended code changes that the California Energy Commission will be considering for adoption in 2021. If you have comments or suggestions prior to the adoption, please email info@title24stakeholders.com*. Comments will not be released for public review or will be anonymized if shared.*

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 Code (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. This CASE Report also includes code change information for Title 24, Part 11 which is the California Green Buildings Standards Code (CALGreen). The Statewide CASE Team will be submitting a separate report that further details CALGreen proposals. 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.

This CASE Report presents a code change proposal that aims to reduce the frequency of steam traps failing, and if steam traps fail, to reduce the time period between failure and when the steam trap is replaced or repaired. Steam is employed to transfer energy in the form of heat or mechanical pressure, as required for the process operation. Efficiency in the steam system results in less energy loss and lowers the fuel consumption required to maintain the process. Industrial users are expected to continue consuming natural gas as a fuel source for steam boilers for at least the duration of the

2022 code cycle, and this measure has significant natural gas use reductions and the potential to lower greenhouse gas emissions.

Measure Description

Background Information

Steam, the gas formed when water passes from the liquid to gaseous state, has high heating value and potential energy properties. Steam systems are commonly used in industrial processes, space heating, and power generation. Applications for steam include heating, propulsion/drive, sterilization, and humidification. California's thriving industrial sector[1] uses steam systems for an array of industrial processes including chemical production plants, building component pulp and paper plants, food processing (meat packing, canning, etc.), assembly factories, and oil refineries.

Steam systems are reliable and require relatively little maintenance. Industrial engineers are likely to continue to use steam systems for the foreseeable future. With the current market conditions and technology availability, steam will remain prevalent and will continue to serve both new and existing facilities. From 1990 to 2020, industrial production in the United States (U.S.) increased at an effective rate of 1.8 percent per year (Board of Governors of the Federal Reserve System (US) 2020). Given steam systems, most of which produce steam using natural gas boilers, are expected to operate into the future even as the rest of the building sector transitions to all electric renewable power, it is important that steam systems operate efficiently to minimize natural gas use and associated greenhouse gas emissions.

While steam systems can reliably provide useful service (i.e., heat, propulsion, sterilization, and humidification), producing steam is energy intensive. Most systems use natural gas boilers to produce steam, and it follows that the industrial sector accounts for a significant portion of statewide energy, natural gas, and GHG emissions. In 2017, California's statewide greenhouse gas emissions were 424.1 million metric tons CO_2 equivalent; the industrial sector accounted for 21 percent of statewide emissions (California Air Resources Board 2019). The industrial sector (including agriculture) is responsible for 23 percent of California's total annual energy use, with most energy use associated with industrial processes (California Energy Commission 2019). A large portion of this energy consumption, industrial natural gas consumption,

[1] More than 700 industrial sites are required to report to the California Air Resources Board through the Cap-and-Trade Program (https://ww2.arb.ca.gov/mrr-data). Types of industrial facilities in California include: food processing, refining, cement, glass, chemicals, construction (California Energy Commission 2020). California was ranked first in the nation in 2018 in terms of manufacturing gross domestic product (California Energy Commission 2020).

has been higher than any other end use Since 2016 (U.S. Energy Information Administration 2020).

The proposed code changes presented in this report will result in significant natural gas savings and associated GHG emissions reductions by minimizing steam waste. This would be accomplished by reduce the frequency of steam traps failing, and if steam traps fail, reducing the time period between failure and when the steam trap is replaced or repaired.

Most steam traps have moving parts that degrade over time and eventually fail. Figure 2 in Section 2.2.1 illustrates two steam trap types, showing moving valves and outlets for condensate. 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. The proposed measure aims to reduce the time a steam trap is left in a failed position, especially in the open (blow-through) position. The primary concern with open failures is that they can go unnoticed for extended periods of time and the associated equipment can continue to operate while wasting energy. Steam traps that fail in the closed position that are part of a drip leg serving a steam line are not necessarily noticed immediately but these failed traps can result in condensate not being removed from a steam line, which in turn can be the source of water hammer, a safety and equipment damage concern.

Steam Trap Failure and Fault Detection and Diagnostics

Automatic steam trap monitoring through fault detection and diagnostics (FDD) can instantly report a failure, eliminate delays in locating failures, and reduce the labor required by manual checks. Steam trap FDD systems are available from multiple sources including the manufacturers of steam traps and manufacturers of industrial and building controls.

Automatic steam trap FDD systems use steam trap fault detection sensors that monitor the conditions of the traps and, upon detection of a fault, send a signal to the central steam trap FDD system. The central steam trap FDD system then transmits an alarm to the facility operator, identifying which steam trap 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.

Strainer and Blow-off Valve Assembly

Strainers in steam distribution systems are in-line metal screens that filter and separate solid matter allowing steam and condensate to pass through, reducing the amount of debris and other contaminants that could enter a steam trap. 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 (see Figure 3 in Section 2.2.1). Installing strainers and blow-off valves upstream of steam traps increases steam trap effective useful life and makes failures less likely, quantified by the time between failures. This code proposal would codify steam system best practices for installation of strainers and blow-off valves in addition to automatic steam trap monitoring. Installing strainers and blow-off valves for all steam trap strainers in new industrial facilities and steam traps serving new industrial process equipment in existing industrial facilities would increase the duration between steam trap failures.

Impact of Proposed Code Changes

The proposed code change would impact the largest natural gas new construction end uses in California, all covered process steam systems, which includes oil and gas refineries, food processors, pharmaceuticals and manufacturing operations that use steam traps with connected steam line operating pressures greater than 15 pounds per square inch gauge (psig) and with total combined connected boiler input capacity rating greater than or equal to 5,000,000 Btu/hr (5.0 MMBtu/hr). The proposed code does not impact space heating or domestic hot water heating applications. The measure only impacts high-pressure steam systems and does not impact low-pressure boiler steam supplied systems. Per the California Department of Industrial Relations, Boiler and Fired Pressure Vessel Safety Order, Subchapter 2 Article 2 Definitions, a low pressure boiler is defined as one that does not "[o]perate at steam pressure or with steam safety valve settings exceeding 15 psi[g]" (CA Department of Industrial Relations 1981).

Proposed Code Change

The proposed code change is designed to reduce energy waste from industrial steam systems by minimizing the time between steam trap failure and replacement, and by increasing the longevity of steam traps. The two specific recommendations are:

1. **Automatic Steam System Fault Detection and Diagnostics (FDD).** Steam systems would be required to have central FDD monitoring systems that detect when a steam trap fails and report that information to the facility operator or facility maintenance staff. The central FDD monitoring system must report the status of each steam trap no less than once every eight hours. If a steam trap fails, the central FDD system must be capable of automatically generating an alarm that indicates which steam trap has failed. The proposed code change would also require that each steam trap have fault detection sensors that are

capable of communication with the central FDD monitoring system. This code requirement would add a new acceptance test to verify that the central FDD monitoring system is installed and operating according to code requirements.

2. **Steam Trap Strainer and Blow-off Valve Assembly.** Each steam trap in the steam system would be required to be protected with a strainer and blow-off valve assembly. This could be accomplished by either using steam traps with integral strainer and blow-off valve assemblies or designing the steam system so that each steam trap would be installed within three feet downstream of a strainer and blow-off valve assembly.

The Statewide CASE Team considered several options to apply the requirements to steam systems in California. Each option described below and in Section 3.2.4 would allow the state to realize the energy and GHG savings along different time horizons:

- Option A: Under this option, the proposed requirements would only apply to new industrial facilities[2] or new processes added to existing facilities.
- Option B: Under this option the proposed requirements would apply to the systems identified in Option A (new facilities or lines) and the portions of existing steam systems that are served by equipment that is replaced at the end of life.
- Option C: Under this option, the proposed requirements would apply to all replacement steam traps.

The Statewide CASE Team recommends that the Energy Commission adopt Option C and apply the proposed requirements to all steam systems that meet the cost-effectiveness threshold. Doing so will result in significant natural gas savings and GHG reductions. Under Option A, the state may never achieve the full potential energy and GHG savings as the requirement will only apply to new process operations. Existing facilities would be exempt. Under Option C, the full savings potential could be achieved in four to five years.

Although the Statewide CASE Team recommends that the Energy Commission implement Option C for Title 24, Part 6 based on cost effectiveness and energy savings, the Energy Commission has indicated a preference for a proposal that applies requirements only to new facilities and new process lines (Option A, which is the smallest scope) for the 2022 Title 24, Part 6 Standards. This report therefore describes applying the requirements in accordance with Option A for Title 24, Part 6 and recommends developing requirements for CALGreen that would apply

[2] Section 100.1(b) of Title 24, Part 6 includes the following definition as one of the nonresidential building occupancy types “Industrial/Manufacturing Facility Building is a building with building floor area used for performing a craft, assembly or manufacturing operation.

recommendations more broadly, if the measures were adopted by jurisdictions through Reach Codes.

The proposed Title 24, Part 6 changes would be mandatory and would add a new subsection to Section 120.6 of Title 24, Part 6. The requirements would apply to newly constructed process facilities and new production lines within existing facilities. It would only apply to steam systems that have greater than 15 pounds per square inch gauge (psig) of connected steam line pressure and a connected boiler capacity greater than 5.0 million British thermal units per hour (MMBtu/hr).

The two-tiered recommendations for CALGreen would require steam trap FDD and steam trap strainers on steam systems that undergo major equipment replacements (Tier 1, consistent with Option B) and all steam trap replacements (Tier 2, consistent with Option C). As with the Title 24, Part 6 proposal, the CALGreen requirements would only apply to systems with a connected steam pressure greater than 15 psig and a connected boiler capacity of 5MMBtu or greater.

Neither Title 24, Part 6 nor Title 24, Part 11 currently regulate the installation of steam traps or require the installation of a strainer with a blow-off valve. The proposed code change represents additions to Title 24, Part 6 and Title 24, Part 11 where none previously existed.

Scope of Code Change Proposal

Table 1 summarizes the scope of the proposed changes to Title 24, Part 6 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). See Appendix I for recommended revisions to Title 24, Part 11.

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 FDD and Steam Trap Strainers	Mandatory	120.6(j)	Nonresidential Appendix 7	No	New form: NRCA-PRC-17-F Modified forms: • 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: steam supply/generation source, steam distribution, end use equipment/processes and condensate return systems (see Figure 1). Steam is generated by steam boilers which is an energy intensive process, although heat recovery can sometimes be used to improve overall efficiency. Steam traps are mechanical devices that separate live steam from condensate and air. 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 FDD can support a robust maintenance program by providing early identification of failed steam straps.

Automatic steam trap FDD 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. Average life expectancy for steam traps without strainer and blow-off valve assemblies and steam trap automatic monitoring systems are four and ten years, respectively. The steam trap FDD 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 were estimated to have an average of six-year life expectancy. Therefore, the steam trap strainer installation measure also utilizes the 15-year measure life evaluation. 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.

Both the monitoring and strainer components of this proposal are cost effective over the 15-year period of analysis.

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. The benefit-to-cost (B/C) ratio compares the benefits or energy 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 FDD is 2.62, and for steam trap strainer installation is 3.66. 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 carbon savings associated with one million therms is 23 times higher than the savings associated with one GWh. See Section 6 for more details on the first-year statewide impacts and Section 4 for details on the per-unit energy savings calculated by the Statewide CASE Team.

Table 2: First-Year Statewide Energy and Impacts

Submeasures	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (Million Therms)	TDV Energy Savings (million TDV kBtu/yr)
Steam Trap FDD	**0.064**	**N/A**	**3.156**	**803.05**
New Construction	0.064	N/A	3.156	803.05
Alterations	N/A	N/A	N/A	N/A
Strainers	**0.004**	**N/A**	**0.210**	**53.54**
New Construction	0.004	N/A	0.210	53.54
Alterations	N/A	N/A	N/A	N/A
Total	**0.068**	**N/A**	**3.366**	**856.59**

The energy analysis, based on information collected through interactions with stakeholders, assumes that the average facility without automatic monitoring inspects its steam traps annually, so it takes an average of six months to identify a failed steam trap and begin the repair process. Unfortunately, failed open/partial-open traps continue to operate and waste energy during this time. For the steam trap strainer installation analysis, the strainer was assumed to improve the average life expectancy 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 B 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)
Steam Trap FDD	17,227	$1,826,093
Steam Trap Strainer Installation	1,148	$121,740
Total	**18,375**	**$1,947,833**

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 32 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 A.

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)
Steam Trap FDD	N/A	1,786	6.37
Strainer	N/A	595	2.12
TOTAL	N/A	19,098,000	68,000

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 2.5 and Appendix D. The key issues related to compliance and enforcement are summarized below:

- Steam system component manufacturers and installers would need to ensure the systems offered and 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.

- The proposed field verification and acceptance test is new and unfamiliar to market actors (e.g., Installer or other Field Technician).

Field Verification and Acceptance Testing

There is currently no compliance process for steam systems, but there are existing precedents for other industrial measures such as compressed air where a “responsible party,” licensed contractor or engineer, signs the documentation. The proposed code addition includes a field verification construction and acceptance test requirement. Installers could act as field technicians for the acceptance test. See Section 2.5 for a detailed compliance path description.

1. Introduction

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This CASE Report presents a code change proposal that aims to reduce the frequency of steam traps failing, and if steam traps fail, to reduce the time period between failure and when the steam trap is replaced or repaired. Steam is employed to transfer energy in the form of heat or mechanical pressure, as required for the process operation. Efficiency in the steam system results in less energy loss and lowers the fuel consumption required to maintain the process. Industrial users are expected to continue consuming natural gas as a fuel source for steam boilers for at least the duration of the 2022 code cycle, and this measure has significant natural gas use reductions and the potential to lower greenhouse gas emissions.

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, fault detection and diagnostic (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 : 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 B : Environmental Impacts Methodology presents the methodologies and assumptions used to calculate impacts on GHG emissions and water use and quality.
- Appendix C : California Building Energy Code Compliance (CBECC) Software Specification presents relevant proposed changes to the compliance software (if any).
- Appendix D : Impacts of Compliance Process on Market Actors presents how the recommended compliance process could impact identified market actors.
- Appendix E : Summary of Stakeholder Engagement documents the efforts made to engage and collaborate with market actors and experts.
- Appendix F : Nominal Energy Cost Savings presents the energy cost savings in nominal dollars by building type and climate zone.
- Appendix G: Energy Savings and Costs per 5 MMBtu Steam Capacity shows the breakdown of savings by 5 Million Btu/hour, which is the minimum boiler threshold.
- Appendix H: Alternative Code Change Considerations presents a sensitivity analysis with the varied statewide savings that would result from different variations of code applicability.
- Appendix I: Mark-Up Language for CALGreen contains proposed code language for Title 24, Part 11 based on iterations of research, engineering calculations, and stakeholder outreach that went into this Final CASE Report.

2. Measure Description

2.1 Measure Overview

The proposed code change is designed to reduce energy waste from industrial steam systems by minimizing the time between steam trap failure and replacement, and by increasing the longevity of steam traps. The two specific recommendations are:

1. **Automatic Steam System Fault Detection and Diagnostics (FDD).** Steam systems would be required to have central FDD monitoring systems that detect when a steam trap fails and report that information to the facility operator or facility maintenance staff. The central FDD monitoring system must report the status of each steam trap no less than once every eight hours. If a steam trap fails, the central FDD system must be capable of automatically generating an alarm that indicates which steam trap has failed. The proposed code change would also require that each steam trap have fault detection sensors that are capable of communication with the central FDD monitoring system. This code requirement would add a new acceptance test to verify that the central FDD monitoring system is installed and operating according to code requirements. Typical steam system maintenance includes annual inspection of all steam traps. It is possible that some steam traps fail soon after annual inspection and are not replaced for nearly a year. During this time, traps that fail open leak steam into the condensate return system. By adding a steam trap FDD system, the plant operators are alerted soon after steam trap fails and can organize a replacement.
2. **Steam Trap Strainer and Blow-off Valve Assembly.** Each steam trap in the steam system would be required to be protected with a strainer and blow-off valve assembly. This could be accomplished by either using steam traps with integral strainer and blow-off valve assemblies or designing the steam system so that each steam trap would be installed within three feet downstream of a strainer and blow-off valve assembly. Strainers protect the steam trap from debris, prevent clogging from contaminants, and prevent the valve inside to the steam trap from closing. Steam traps without strainers fail more frequently and leak more steam.

The Statewide CASE Team considered several options to apply the requirements to steam systems in California. Each option described below and in Section 3.2.4 would allow the state to realize the energy and GHG savings along different time horizons:

- Option A: Under this option, the proposed requirements would only apply to new industrial facilities[3] or new processes added to existing facilities.

- Option B: Under this option the proposed requirements would apply to the systems identified in Option A (new facilities or lines) and the portions of existing steam systems that are served by equipment that is replaced at the end of life.
- Option C: Under this option, the proposed requirements would apply to all replacement steam traps.

The Statewide CASE Team recommends that the Energy Commission adopt Option C and apply the proposed requirements to all steam systems that meet the cost-effectiveness threshold. Doing so will result in significant natural gas savings and GHG reductions. Under Option A, the state may never achieve the full potential energy and GHG savings as the requirement will only apply to new process operations. Existing facilities would be exempt. Under Option C, the full savings potential could be achieved in four to five years.

Although the Statewide CASE Team recommends that the Energy Commission implement Option C for Title 24, Part 6 based on cost effectiveness and energy savings, the Energy Commission has indicated a preference for a proposal that applies requirements only to new facilities and new process lines (Option A, which is the smallest scope) for the 2022 Title 24, Part 6 Standards. This report therefore describes applying the requirements in accordance with Option A for Title 24, Part 6 and recommends developing requirements for CALGreen that would apply recommendations more broadly, if the measures were adopted by jurisdictions through Reach Codes.

The proposed Title 24, Part 6 changes would be mandatory and would add a new subsection to Section 120.6 of Title 24, Part 6. The requirements would apply to newly constructed process facilities and new production lines within existing facilities. It would only apply to steam systems that have greater than 15 pounds per square inch gauge (psig) of connected steam line pressure and a connected boiler capacity greater than 5.0 million British thermal units per hour (MMBtu/hr).

The two-tiered recommendations for CALGreen would require steam trap FDD and steam trap strainers on steam systems that undergo major equipment replacements (Tier 1, consistent with Option B) and all steam trap replacements (Tier 2, consistent with Option C). As with the Title 24, Part 6 proposal, the CALGreen requirements would

[3] Section 100.1(b) of Title 24, Part 6 includes the following definition as one of the nonresidential building occupancy types “Industrial/Manufacturing Facility Building is a building with building floor area used for performing a craft, assembly or manufacturing operation.

only apply to systems with a connected steam pressure greater than 15 psig and a connected boiler capacity of 5MMBtu or greater.

Neither Title 24, Part 6 nor Title 24, Part 11 currently regulate the installation of steam traps or require the installation of a strainer with a blow-off valve. The proposed code change represents additions to Title 24, Part 6 and Title 24, Part 11 where none previously existed.

2.2 Measure History

2.2.1 Background on Steam Systems

Steam, the gas formed when water passes from the liquid to gaseous state, has high heating value and potential energy properties. Steam systems are commonly used in industrial processes, space heating, and power generation. Applications for steam include heating, propulsion/drive, sterilization, and humidification. California's thriving industrial sector[4] uses steam systems for an array of industrial processes including chemical production plants, building component pulp and paper plants, food processing (meat packing, canning, etc.), assembly factories, and oil refineries.

Steam systems are reliable and require relatively little maintenance. Industrial engineers are likely to continue to use steam systems for the foreseeable future. With the current market conditions and technology availability, steam will remain prevalent and will continue to serve both new and existing facilities. From 1990 to 2020, industrial production in the United States (U.S.) increased at an effective rate of 1.8 percent per year (Board of Governors of the Federal Reserve System (US) 2020). Given steam systems, most of which produce steam using natural gas boilers, are expected to operate into the future even as the rest of the building sector transitions to all electric renewable power, it is important that steam systems operate efficiently to minimize natural gas use and associated greenhouse gas emissions.

While steam systems can reliably provide useful service (i.e., heat, propulsion, sterilization, and humidification), producing steam is energy intensive. Most systems use natural gas boilers to produce steam, and it follows that the industrial sector accounts for a significant portion of statewide energy, natural gas, and GHG emissions. The industrial sector (including agriculture) is responsible for 23 percent of California's total annual energy use, with most energy use associated with industrial processes

[4] More than 700 industrial sites are required to report to the California Air Resources Board through the Cap-and-Trade Program (https://ww2.arb.ca.gov/mrr-data). Types of industrial facilities in California include: food processing, refining, cement, glass, chemicals, construction (California Energy Commission 2020). California was ranked first in the nation in 2018 in terms of manufacturing gross domestic product (California Energy Commission 2020).

(California Energy Commission 2019). A large portion of this energy consumption, industrial natural gas consumption, has been higher than any other end use for the past few years (U.S. Energy Information Administration 2020). California industrial energy consumption corresponds to approximately 21 percent of California's 424.1 million metric tons CO_2 equivalent of statewide greenhouse gas (GHG) emissions (California Air Resources Board 2019).

In industrial process applications, steam systems consist of four main subsystem components: steam supply/generation source, steam distribution, end use equipment/processes and condensate return systems (see Figure 1). As energy is transferred along steam system piping, steam cools and condenses, and water eventually returns to the boiler (TLV SteamWorld 2020).

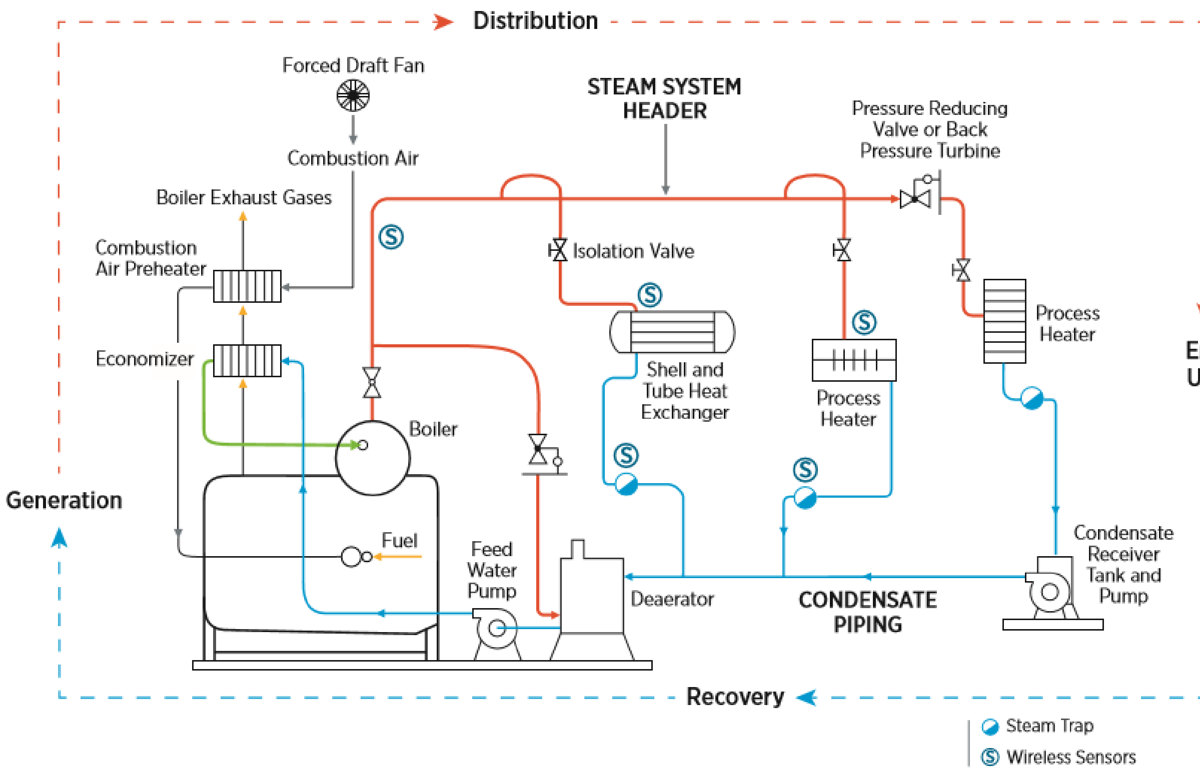

Figure 1: Steam system schematic.

Source: (Energy n.d.)

Steam traps, including the common types depicted in Figure 2, are mechanical valves that separate live steam from condensate (i.e., liquids) and non-condensables (e.g., air), allowing maximum steam energy to be employed by the industrial process. Steam is regularly used as a heating and/or driving force for mechanical power within the industrial sector, and steam traps are used to ensure that steam is not wasted. Often, steam traps are located immediately after a heating process or to drive mechanical power in industrial process applications. A steam trap's primary function for heating processes is to hold back steam until it condenses, passing the steam's latent heat into the system.

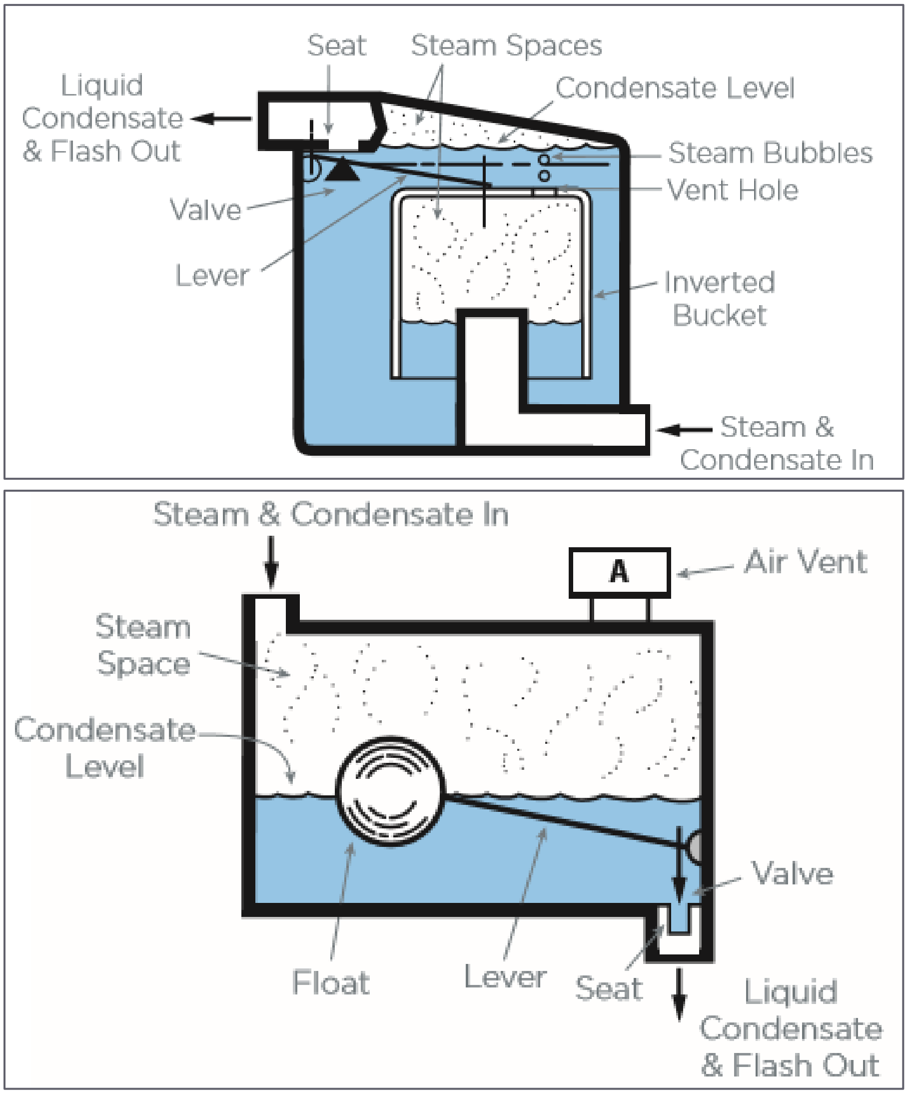

Figure 2: Two common types of steam trap: Inverted bucket steam trap (top) and float and thermostatic steam trap (bottom).

Source: (Energy n.d.)

Strainers in steam distribution systems are in-line metal screens that 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 (see Figure 3). Installing strainers and blow-off valves upstream of steam traps increases steam trap life and makes failures less likely by reducing the amount of debris and other contaminants that enter a steam trap, thereby increasing its effective useful life, quantified by the time between failures. Installing strainers and blow-off valves for all steam trap strainers would increase the duration between steam trap failures.

Section 2.2.2 goes into further description of steam trap failures and the impact of failed equipment on the system.

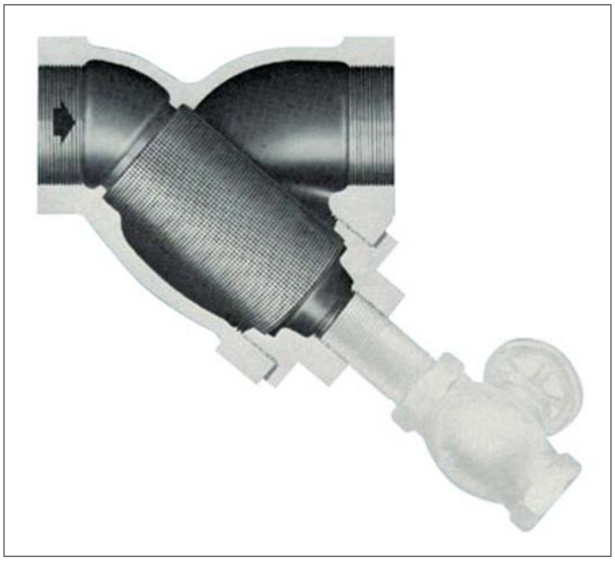

Figure 3: Strainer with blow-off valve to the bottom.

Source: (StrainerSales n.d.)

2.2.2 Steam Trap Failure and FDD

Most steam traps have moving parts that degrade over time and eventually fail in either open, closed, or partially open condition. Failure in a partially open condition often results from a solid contaminant in the steam system that clogs the steam traps. If steam traps fail in a closed position, heating stops in the upstream device. This type of failure is often identified quickly, and the trap is repaired.

When steam traps fail in the open or partially open position, steam will continue to flow through the system. Since the system can continue process operations, the failed steam trap may go unrepaired for an extended period. In those failed open or partially open positions, uncondensed steam passes through the steam trap and is released to the environment through the condensate return system as wasted energy and wasted treated water. This greatly decreases the system efficiency. This is analogous to a steam leak in a steam pipe. The energy in the released steam is lost to the environment without doing useful work. The difference for leaking steam traps is that the leaking steam is not immediately evident because the steam does not directly leak into the air but leaks into a condensate pipe and is transferred back to the deaerator tank, along with condensate from many other steam traps. In Figure 4, the steam traps, indicated by the half shaded circles, pass steam into the condensate piping, on into the deaerator tank and out into the environment through the vent stack on the deaerator tank.

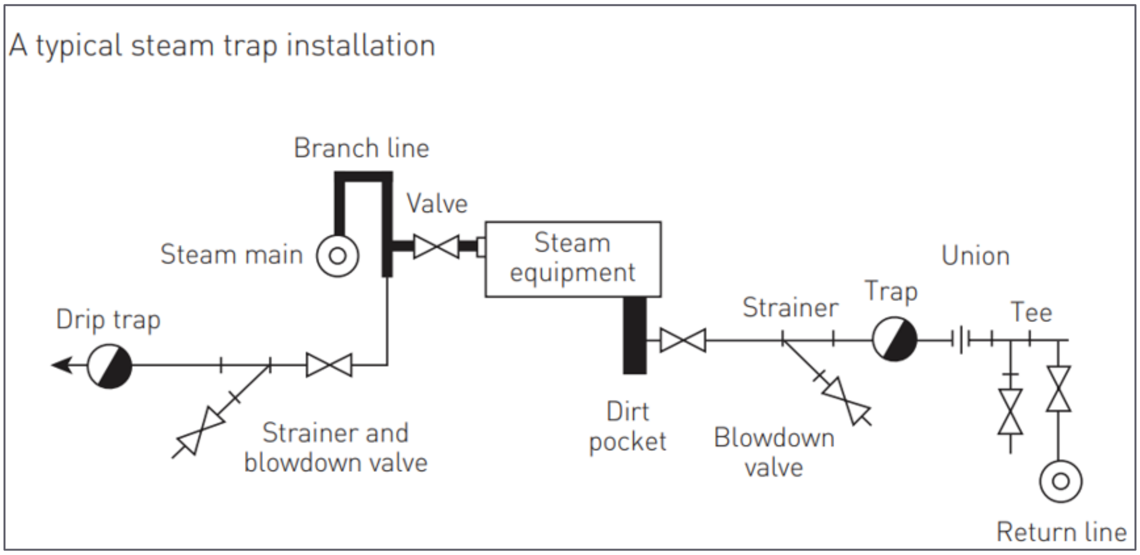

Figure 4: A typical steam trap, strainer and blow-off ("blowdown") valve assembly installation.

Source: (Traps n.d.)

Automatic steam trap monitoring through FDD can report a failure to the operator or maintenance staff instantly, (although the recommended code change requires that the system be capable of reporting once every eight hours) eliminating the labor required by manual checks.

The FDD portion of the proposed code would reduce the average time a steam trap is left in a failed position, specifically an open (blow-through) position. The FDD steam trap FDD systems have sensor notifications that would alert facility maintenance staff of a failure more quickly than the typical manual inspection would. FDD systems are commonly installed to support identification of potential energy waste, and can also be installed on process critical applications, hard to access locations, or on steam traps that pose an elevated safety risk.

While the exact 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.

2.2.3 Strainer and Blow-off Valve Assembly

In addition to reducing the duration between steam trap failure and replacement, this proposal is designed to extend the life of steam traps between failures by requiring steam traps with integral strainers and blow off valves or a strainer and blow off valve immediately upstream of the steam trap. Installing strainers and blow-off valves (see Figure 4) upstream of steam traps increases steam trap life and decreases the likelihood of failures described in Section 2.2. This code proposal would codify steam system best practices for installation of strainers and blow-off valves in addition to automatic steam strap monitoring.

Multiple stakeholders indicated that protecting steam traps with strainers extends the life of steam traps and is considered standard good practice. In the case of steam traps that are more sensitive to failure, such as disk type steam traps, these are almost always protected and quite often are installed with an integral strainer. CASE Authors directly asked stakeholders if there were any contraindications associated with the use of strainers, and no stakeholders responded with any. The average benefit of strainers was described as increasing the mean time between failure for steam traps from four years to six years. Therefore, installing strainers saves energy as this increases the period between steam trap failures. Installing strainers upstream of traps also reduces the annualized cost of steam trap repairs as these repairs occur less frequently.

2.3 Summary of Proposed Changes to Code Documents

The sections below summarize how Title 24, Part 6 would be modified by the proposed code changes including revisions to the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals. See Section 7 of this report for detailed proposed revisions to code language. Revisions to Title 24, Part 11 are discussed in Appendix I.

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 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. The purpose of the proposed change to this section is to add a definition for the term “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(j): Mandatory Requirements for Steam Traps: The purpose of the proposed change to this section is to include new mandatory requirements for steam traps. 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 15 psig and with boiler capacity greater than 5.0 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

- **NA7.21 –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(j).

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 NA7.21 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 created and added to the existing set of compliance documents. This new document would be submitted to the enforcement agency that certifies the equipment and systems meet the acceptance requirements in NA7.21 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

Neither Title 24, Part 6 nor Title 24, Part 11 include relevant existing requirements for steam distribution systems, steam traps, steam trap 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.

Title 24, Part 6, Section 120.6(e) outlines mandatory requirements for compressed air systems, providing a precedent for industrial and factory regulations. There are no existing requirements in Title 24, Part 6 for pipe sizing, monitoring, or leak testing of compressed air piping but the measures proposed for the 2022 language update build upon existing requirements by revising existing code language for clarity and ease of compliance and adding additional requirements for pipe sizing, leak testing, and monitoring of compressed air piping.

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

There were no identified conflicting overlaps with requirements in the California Mechanical Code (CMC).

2.4.3 Relationship to Local, State, or Federal Laws

Statewide CASE Team research efforts including stakeholder outreach, online 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. The Department of Energy does have a webpage specifically dedicated to the importance of steam system efficiency with dozens of targeted resources, noting "[m]any manufacturing facilities can recapture energy by installing more efficient steam equipment and processes and applying energy management practices" (Office of Energy Efficiency and Renewable Energy n.d.).

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 D 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 steam systems in new industrial facilities or new processes added to existing facilities. 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 systems are subject to code requirements. Steam systems that are to comply with the code would need to have a central steam trap FDD monitoring system (Section 120.6(j)1) and each steam trap in the system must have an automatic fault detection sensor and communicate with the central steam trap FDD monitoring system (Section 120.6(j)2). Each steam trap in the system must also be protected with a strainer and blow-off assembly (Section 120.6(j)3). 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 steam traps serving new industrial facilities and steam traps serving new industrial process equipment in existing industrial facilities. 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(j) 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.

  For some large industrial facilities, work that falls under various section of Title 24 is ongoing and individual permits are not being pulled for every modification to the plant. The local jurisdiction might have an annual permit, which is an open permit to conduct a variety of repair and replacement work. Often there is an Inspector of Record on site to assure work is being conducted according to codes and best practices and they are reporting to the local jurisdiction on a periodic basis. When a plant has tens or hundreds of steam traps being replaced on a periodic basis, the annual permit results in less paperwork as the code compliance reporting can be aggregated.

- **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(j). The design and permit application phases would define the equipment specifications pertaining to code Section 120.6(j). Installers would perform work detailed in the design documents to satisfy all code compliance. Upon completion of installed equipment, the responsible party would complete acceptance test(s) defined in Section NA7.21, as required. The acceptance test could be conducted by the installing technician, including facilities staff at the industrial facility. However, the acceptance testing forms would also have to be signed by a “responsible party,” such as a licensed contractor or a licensed engineer, who would be able to sign the necessary compliance documentation. If the work is being conducted by plant staff a licensed plant engineer could sign as the responsible party. NRCI-PRC-01-E and NRCA-PRC-17-F would be filled out by the field technician. The installer could also act as the field technician for conducting the test.

- **Inspection Phase:** The proposed code change is expected to impact the inspection phase. The inspection phase for all steam traps serving new industrial facilities and steam traps serving new industrial process equipment in existing industrial facilities would require submittal of Certification forms, NRCI-PRC-01-E and NRCA-PRC-17-F, to the local jurisdiction Building Department.

Currently there is no compliance process for steam systems. 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 for these market actors prior to the code change taking effect to reduce compliance challenges. The structure of the compliance process has been 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. 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 steam traps serving new industrial facilities and steam traps serving new industrial process equipment in existing industrial facilities to 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, manufacturer representatives, distributors, 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 and associated product trade names have been identified as either component or system manufacturers of FDD systems. Those with California headquarters are denoted with an asterisk:

- Armstrong International, Steameye®
- Bitherm, SmartWatchWeb™
- Cypress Envirosystems*, Wireless Steam Trap Monitor (WSTM)
- Emerson, Rosemount™
- Everactive*, Steam Trap FDD (STM)
- Honeywell, Thermal IQ™
- Spirax Sarco, STAPS Wireless, and
- SteamIQ, SteamIQ.

The FDD market is dominated by add-on component system packages that can be easily and non-invasively installed on most steam traps while steam traps specifically designed for integral steam trap FDD sensors are limited. Generally, FDD systems can be installed independently 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 equal to or 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 determined greater than 15 psig to be economically practical.

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 FDD 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 FDD 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 open to the sales engineer or mechanical contractor performing the installation, including steam trap, strainers and blow-off valve assemblies, and isolation valves, as well as the specific positioning of the components during 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

3.2.1 Market Availability and Current Practices

Market adoption of steam trap FDD systems has been growing. 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.

Steam trap monitoring systems are available from multiple sources, including the manufacturers of steam traps and manufacturers of industrial and building controls. FDD systems use steam trap fault detection sensors that monitor the conditions of the traps and send a signal to a centralized monitoring system upon detection of a fault. The central system then transmits an alarm to the facility operator, identifying which steam trap 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.

There are multiple FDD options for steam traps, including wired and wireless FDD systems. Data recording durations vary from a fraction of a second (spot measurement) to a minute or longer depending on the specific product. Different systems can upload data to the centralized monitoring a few times a day or go down to real-time. Everactive employs a battery-less sensor for steam trap FDD that provides real-time alerts and notifications via “continuous sensing and wireless transitions” to provide maximized returns and eliminate the need for battery replacements for its customers. For this product, data sampling and transmission occurs every 60 seconds, as the battery-less sensors are powered from heat of steam pipe or indoor solar and can essentially operate battery maintenance free in perpetuity. Alternatively, other vendors have elected to reduce battery consumption by sampling less frequently, often only a few times per day, but using longer recording durations. This method too has proven to provide a reliable data set to indicate the operating condition of the steam trap.

Other steam trap end-users note that “steam traps are often installed in inconvenient places, such as crawl spaces, inside walls or mounted on high ceilings” and that use of wireless monitors, such as SteamIQ, allows those difficult traps to be monitored without manual testing (Senet n.d.). The SteamIQ system has the capability to record and send information at set intervals, and the company has optimized their data collection and battery life with minute long recorded data sent into the centralized monitoring system at 8-hour intervals.

3.2.2 Energy Savings Opportunity – FDD

Steam trap monitoring FDD products provide notification that a fault has occurred when 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. As detailed in the Department of Energy’s Steam System Sourcebook, end-users improve profits with data from wireless sensors at steam traps by continuously monitoring and alarming for leakage (U.S. Department of Energy 2012). 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. It is less expensive to continuously monitor steam traps and not lose product versus paying either an employee or outside firm to survey annually and accept the losses and downtime (F. (2), 10292019 - FDD (2) –FDD Manufacturer (2) 2019).

Due to the nature of this energy savings measure, persistence of savings would be 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. Automatic steam trap FDD 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. As discussed in Section 4.1, the Statewide CASE Team assumed that maintenance staff would fix a failed trap soon after being alterted of a falut 95 percent of the time.

Case studies, stakeholder feedback, and other resources discussed in this report point to the benefits of implementing monitoring as an energy efficiency measure. Other industrial applications, such as compressed air, have also shown success in using monitoring as well.

A 2019 study funded through the Electric Program Investment Charge (EPIC) and published by the Energy Commission evaluated covered process monitoring solutions at 102 participant locations, finding clear, cost-effective benefits and customer satisfaction. The goal of installing the system was "to enable energy optimization by acquiring high resolution energy consumption data in real-time, identifying and generating insights from the data (i.e., identify and calculate leakage), and triggering alerts and actions for the facility's staff." While this report focused on opportunities within compressed air systems, participants also presented other pain points within industrial operations. These varied by industry, but steam systems were explicitly identified as one of these additional industrial processes that could benefit from a similar centralized monitoring system (Greenstone, et al. 2019).

3.2.3 Maintenance Requirements

FDD systems have their own set of maintenance requirements including power supply, sensor, and communication equipment subsystems. 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. According to one stakeholder, it is always beneficial to have a strainer especially on steam traps that are susceptible to failure from dirt and other particulate to reduce the frequency of steam trap failure and steam wasted (F. (4) 2019).

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 Section 7. End-users may be minimally and temporarily affected by the functional testing acceptance requirement.

3.2.4 Alternative Code Change Considerations

The Statewide CASE Team considered several options before arriving at the proposed code changes presented in this report. As discussed in Section 2.2, California has many process steam systems. There is substantial evidence that improving steam trap longevity (strainer and blow-off valves) and reducing the time between trap failure and trap replacement (automatic steam trap FDD) reduces energy wasted from steam systems. The Statewide CASE Team encourages the Energy Commission to pursue code changes that will allow California to realize the energy savings from all steam systems in the state as quickly as possible. This includes considering code requirements that result in energy savings from newly constructed facilities, new process lines within existing facilities, and capturing savings from existing facilities and process lines. The three code options described below would allow the state to achieve varying quantities of savings. The recommended code requirements remain the same—require automatic steam trap FDD systems and require steam traps to be protected by strainers and blow-off valves—however, the type of systems that the requirements would apply to vary in each option.

- Option A: Under this option, the proposed requirements would only apply to new industrial facilities or new processes added to existing facilities. Process lines could include production or assembly configurations, so factories adding these entire new processes would have a large-scale construction project that would already require building department involvement and permitting. There are relatively few new steam systems added in California. Under this option, the proposed requirements would not apply to existing facilities. The statewide energy and GHG savings will be significantly smaller than applying the proposed requirements more broadly, as discussed in Options B and C.
- Option B: Under this option, the proposed requirements would apply to the systems identified in Option A (new facilities or lines) and the portions of existing steam systems that are served by equipment that is replaced at the end of life. Under Option B, the central steam trap FDD monitoring system would need to be installed at the time equipment is replaced. Equipment that would trigger the steam trap FDD requirement includes the following examples: evaporator columns, shell and tube heat exchangers, jacketed kettles, reboilers, etc. The code requirement would require steam traps that are connected to the same steam distribution line as the replaced code, triggering industrial process equipment to simultaneously be replaced. It is estimated that the average effective useful life (EUL) of the industrial process equipment is generally 20

years. Under this option, all steam traps in the state would be compliant with the proposed requirements in approximately 25 years, the same duration of time which the process equipment replaced (20 years) plus four to five years to replace all steam traps associated with the replaced equipment after the trap fails.

- Option C: Under this option, the proposed requirements would apply to all replacement steam traps. Once the requirement would take effect, upon the first trap failure the facility would need to install the central FDD monitoring systems. Each newly installed trap would need to have fault detection sensors and comply with the strainer and blow-down requirements. Under this option, all steam traps in the state would comply with the proposed code changes in approximately four years (four-year average trap life).

All three options were found to be cost effective. The Statewide CASE Team recommends that the Energy Commission opt to apply the proposed requirements to all steam systems that meet the cost-effectiveness threshold (15 psig of connected steam pressure and 5MMBtu/hr connected boiler capacity). Doing so will result in significant energy and GHG savings. See Appendix H for a summary of the energy and GHG savings from each option.

Pursuing Option C instead of Option A would result in an additional first year natural gas savings of 38.8 million therms/year of natural gas savings and corresponding 211,792 metric tons CO2e of total reduced emissions.

Although the Statewide CASE Team recommends moving forward with adopting the requirements in accordance with Option C, the Energy Commission primarily expressed interest in Option A which only applies the requirements to new facilities and new process lines. As a result, this report describes applying the requirements in accordance with Option A and recommends moving forward with developing requirements for CALGreen that would apply recommendations more broadly. The Statewide CASE Team is continuing to evaluate CALGreen proposals and will release final Title 24, Part 11 recommendations after the publication of this Final CASE Report. If the Energy Commission decides to pursue Option C and supplemental analysis is needed, the Statewide CASE Team will support the revision as requested, and as time and resources allow.

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 5).[5] 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 5: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establishments	Employment	Annual Payroll (billions $)
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 FDD 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

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

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 6 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 FDD to affect firms that focus on nonresidential industrial steam system construction.

There is not a North American Industry Classification System (NAICS)[6] 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.[7] 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 6 provides an upper bound indication of the size of this sector in California.

Table 6: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billions $)
Architectural Services [a]	3,704	29,611	$2.9
Building Inspection Services [b]	824	3,145	$0.2

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;

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[6] 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.

[7] 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.

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. Water hammer is a phenomenon that can occur in steam systems when steam quickly condenses into water; the rest of the steam picks up the water creating a ballistic type, slug which is propelled at a high rate of speed into sections of pipe or pipe fittings creating a loud hammering noise. This condition occurs when condensate is poorly drained from the steam distribution system. A failed closed trap on a drip service would allow condensate to back up in a steam main which causes the “slug” to form more easily resulting in increased probability that water hammer may occur. 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 (California Energy Commission 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.

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 9,000 new control points annually.

3.3.6 Impact on Building Inspectors

Table 7 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 7: Employment in California State and Government Agencies with Building Inspectors

Sector	Govt.	Establishments	Employment	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 FDD 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 FDD 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.[8] 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

[8] 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.

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.

Table 8: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact: Automatic Steam Trap FDD		Employment (jobs)	Labor Income (millions $)	Total Value Added (millions $)	Output (millions $)
Automatic Steam Trap FDD	Direct Effects (Additional spending by Commercial Builders)	104	$6.91	$9.16	$15.15
	Indirect Effect (Additional spending by firms supporting Commercial Builders)	23	$1.65	$2.64	$5.08
	Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	45	$2.56	$4.58	$7.48
Steam Trap Strainer Installation	Direct Effects (Additional spending by Commercial Builders)	4	$0.23	$0.31	$0.51
	Indirect Effect (Additional spending by firms supporting Commercial Builders)	1	$0.06	$0.09	$0.17
	Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	2	$0.09	$0.16	$0.25
Total Economic Impacts		**179**	**$11.50**	**$16.93**	**$28.66**

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

Table 9: 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 FDD	Direct Effects (Additional spending by Building Designers & Energy Consultants)	2	$0.27	$0.26	$0.47
	Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consult.)	2	$0.11	$0.15	$0.24
	Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	2	$0.11	$0.20	$0.33
Steam Trap Strainer Installation	Direct Effects (Additional spending by Commercial Builders)	1	$0.05	$0.05	$0.09
	Indirect Effect (Additional spending by firms supporting Commercial Builders)	0	$0.02	$0.03	$0.05
	Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	0	$0.02	$0.04	$0.07
Total Economic Impacts		**8**	**$$0.59**	**$0.74**	**$1.25**

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 California Building Inspectors

Type of Economic Impact		Employment (jobs)	Labor Income (millions $)	Total Value Added (millions $)	Output (millions $)
Automatic Steam Trap FDD	Direct Effects (Additional spending by Building Inspectors)	3	$0.25	$0.29	$0.35
	Indirect Effect (Additional spending by firms supporting Building Inspectors)	0	$0.02	$0.03	$0.06
	Induced Effect (Spending by employees of Building Inspection Bureaus and Departments)	1	$0.08	$0.14	$0.24
Steam Trap Strainer Installation	Direct Effects (Additional spending by Commercial Builders)	1	$0.05	$0.06	$0.07
	Indirect Effect (Additional spending by firms supporting Commercial Builders)	0	$0.00	$0.01	$0.01
	Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	0	$0.02	$0.03	$0.05
Total Economic Impacts		**5**	**$0.42**	**$0.56**	**$0.77**

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 15 psig, 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 5MMBtu/hr and with operating pressures higher than 15 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.[9] 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.

[9] 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).[10] As Table 11 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 11: 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 = $482,017

[10] 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 D, 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 final 2022 Time Dependent Valuation (TDV) factors were used for the analyses presented in this report (Energy + Environmental Economics 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 E. 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) and Statewide CASE Team statistical analysis)

- 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 occurrence of the maintenance process being initiated following FDD notification 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. This included requests for information and feedback on underlying assumptions during the release of the Draft CASE Report.

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 FDD-based 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 required for installation on steam traps impacted by the requirement to install FDD.

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 beginning at greater than 15 psig (29.7psia). The methodologies below describe first how individual trap savings, then average savings were determined. The assumptions in Table 12 are based on research and stakeholder outreach.

Section 4.2.1.1 describes in further detail the methodology used to establish a distribution for steam trap orifice size that represents real-world supply and applications as accurately as possible. This additional analysis was required since a single manufacturer-provided “typical” steam trap orifice for each pressure bin but did not indicate the relative sales of other steam trap sizes found in their product catalog. The “typical” orifice diameter is highlighted in Table 14 as well as the alternative steam trap orifice diameters generally available at the corresponding pressure bin (F. (4) 2019).

The methodology to extrapolate individual trap (at 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 12 for all orifice zones for all pressures.
- Step 2: For each pressure bin, make use of manufacturer provided “typical” orifice size with respect to pressure and treat this as the statistical mode (most frequently sold) of the distribution of available orifice sizes for that pressure bin.
- Step 3: Multiply the fraction of each orifice size by its energy savings, to calculate the weighted energy savings per steam trap in each pressure bin.
- Step 4: Calculate the overall weighted average energy savings per trap over all pressures by multiplying by the manufacturer provided relative prevalence of steam traps operating at each pressure bin

To calculate the average strainer energy savings:

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

Table 12: 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	$F_{steam\ trap}$	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 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 (gauge pressure plus 14.7 psi atmospheric pressure)
Varies	D	Steam trap orifice diameter in inches, 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 Orifice Distribution Methodology

This section describes the methodology that the Statewide CASE Team used to extrapolate from the manufacturer-provided description of "typical" (highest selling) steam trap orifice sizes for each pressure class to estimate the energy savings from reduced steam trap leakage by pressure class.

Steam trap orifice sizes and the corresponding annual installations are an important variable for the calculations that inform savings for this measure. However, this same data is closely held as it relates to competitive information for the steam products industry. In general, the most frequently sold products are typically on the smaller end of the range of products available.

Figure 5 shows the range of orifice sizes from one manufacturer's catalog superimposed with orange circles showing the orifice size declared to be typical for each pressure bin, with typical sizes on the lower end of the sizes of products available.

In general, the typical sizes are the first, second, or third smallest orifice size for each pressure. Each pressure can be served by seven to nine different product sizes. Since steam losses are proportional to the square of the orifice size, an orifice twice as large would leak four times as much steam. Therefore, even a relatively small proportion of large steam traps has potential to disproportionately impact total energy savings. As a result, a probability distribution of orifice sizes best characterizes potential savings from steam trap fault detection.

Table 13 tabulates the orifice size for each orifice size bin with respect to pressure bin. Note that orifice sizes are larger for lower pressures. The cells that are highlighted in blue, represent the “typical” orifice size for the pressure bin as relayed to the Statewide CASE Team by one manufacturer. These typical sizes are treated as the mode of the orifice size distribution for that pressure bin.

The Statewide CASE Team used a triangular (arithmetic linear) distribution and considered the mode of the distribution to be a typical orifice size. The directionality of the curve reverses at the typical orifice size; in other words, at each gauge pressure level, orifice sizes smaller than the typical size will have increasing probabilities up to the mode of typical orifice size and with decreasing probabilities for orifice sizes larger than the typical size. Since there are different typical sizes by pressure and different range of orifice sizes by pressure, the distribution is unique for each pressure bin.

Figure 6 provides the mathematical illustration of the solution. The mode is for orifice sizes one to three, while the total number of sizes per pressure bin ranges between seven and nine. The Statewide CASE Team used such probabilities to estimate new and replacement installations at different gauge pressure levels, with results matching expectations that large orifice sizes to be installed less frequently than smaller size options. A variety of different probability distributions could have been used, however this estimate was used because it is relatively simple and it accounts for a range of different orifice sizes in the market while reflecting an assumed distribution that as orifices diverge from the “typical” size (either substantially larger or smaller) there are proportionately less of these other sizes sold.

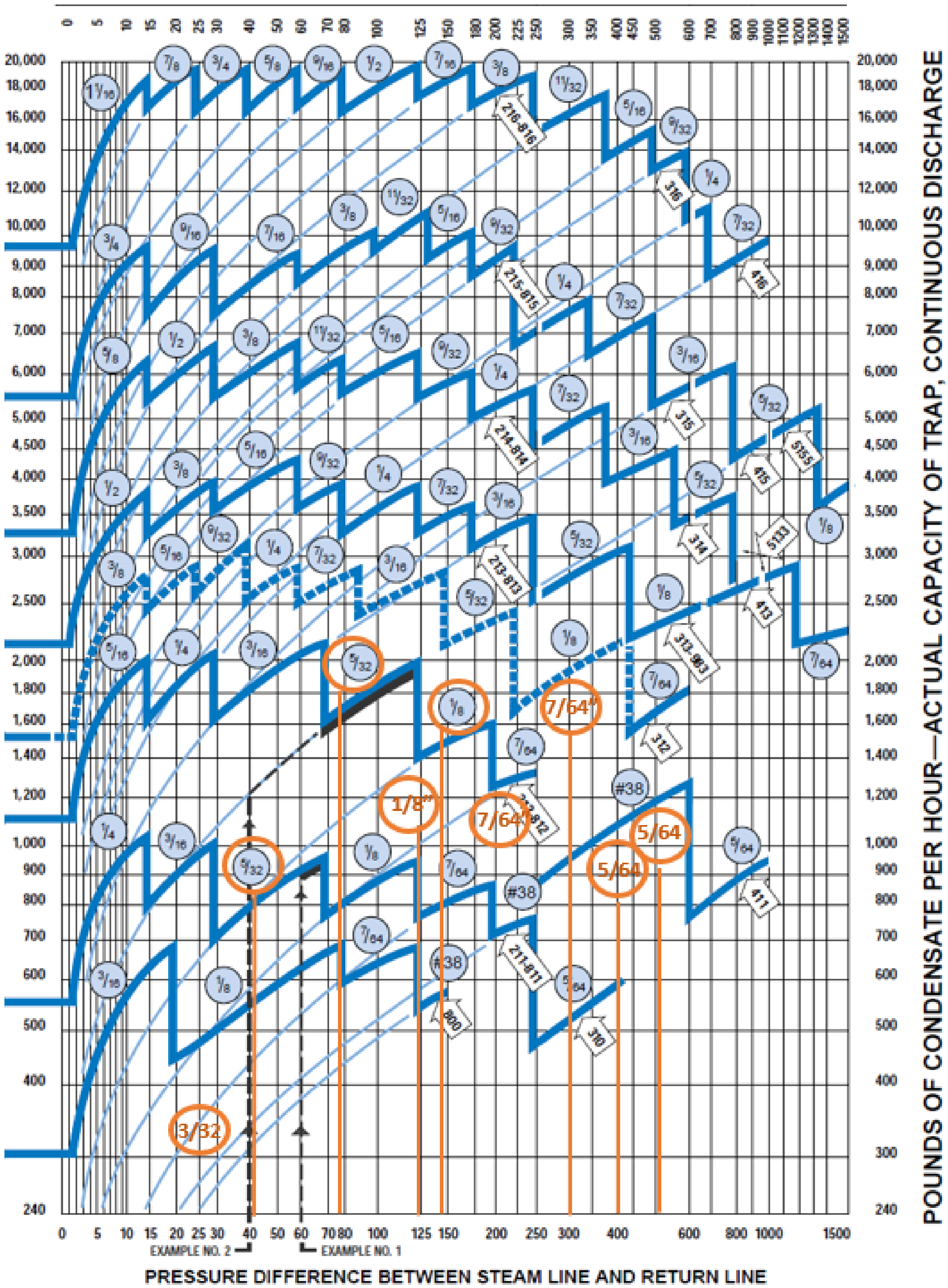

Figure 5: Plot of gauge pressure and orifice size.

Table 13: Orifice Diameter (inches) by Gauge Pressure (psig)

	Orifice1	Orifice2	Orifice3	Orifice4	Orifice5	Orifice6	Orifice7	Orifice8	Orifice9
15	3/16	1/4	5/16	3/8	1/2	9/16	7/8		
30	1/8	5/32	3/16	1/4	9/32	5/16	3/8	7/16	3/4
45	1/8	5/32	3/16	1/4	5/16	3/8	7/16	5/8	
60	1/8	5/32	3/16	7/32	9/32	11/32	3/8	1/2	
80	7/64	1/8	5/32	3/16	1/4	9/32	5/16	11/32	1/2
100	7/64	1/8	5/32	3/16	1/4	9/32	5/16	11/32	1/2
125	7/64	1/8	5/32	3/16	1/4	9/32	5/16	11/32	7/16
150	7/64	1/8	5/32	3/16	1/4	9/32	5/16	11/32	7/16
200	7/64	1/8	5/32	3/16	1/4	9/32	5/16	11/32	3/8
250	5/64	7/64	1/8	5/32	3/16	1/4	9/32	5/16	11/32
300	5/64	7/64	1/8	5/32	7/32	1/4	9/32	5/16	11/32
400	5/64	1/8	5/32	3/16	7/32	9/32	5/16		
500	5/64	7/64	1/8	5/32	3/16	7/32	1/4	9/32	
600	5/64	3/32	1/8	5/32	3/16	7/32	1/4		

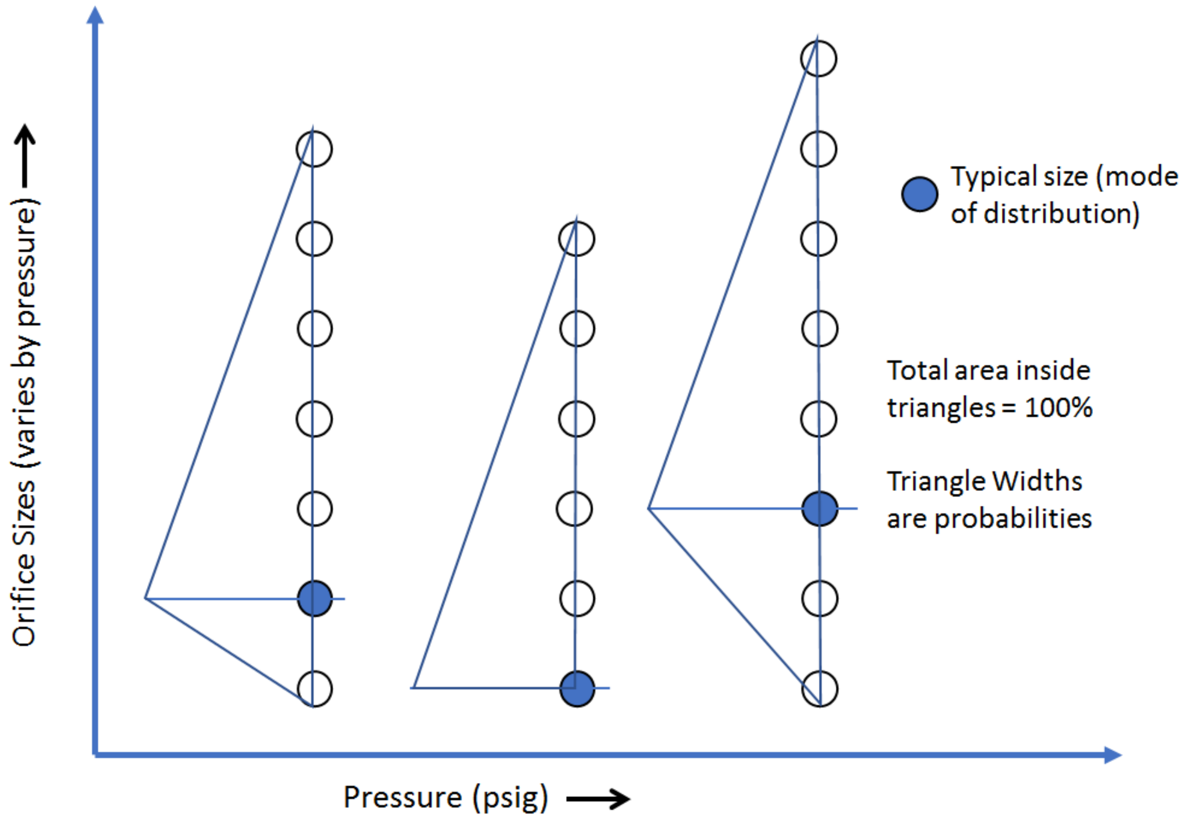

Figure 6: Illustration of mathematical solution used to develop probability distributions of orifice sizes.

The results matched the expectation that large orifice sizes would be installed less frequently than smaller size options. This statistically updated distribution was then used by the Statewide CASE Team in development of measure energy and cost savings calculations.

This distribution is shown in Table 14 for different pressure bins, with most steam traps on the smaller end of the distribution with fewer larger steam traps. However, since steam savings is proportional to the square of the orifice size, the average energy savings is weighted towards the larger orifice sizes.

Table 14: Energy Savings Per Steam Trap Orifice Diameter Per Gauge Pressure Bin

Gauge Pressure (psig)	Orifice 1 (therms/yr)	Orifice 2 (therms/yr)	Orifice 3 (therms/yr)	Orifice 4 (therms/yr)	Orifice 5 (therms/yr)	Orifice 6 (therms/yr)	Orifice 7 (therms/yr)	Orifice 8 (therms/yr)	Orifice 9 (therms/yr)	Weighted Energy Savings, (therms/yr)	Market Share	hfg, Btu/lb
15	76.9	136.6	213.5	307.4	546.6	691.8	1,673.9	0.0	0.0	224.1	10%	945.7
30	50.5	78.9	113.7	202.0	255.7	315.7	454.6	618.8	1,818.4	207.7	11%	929.1
45	66.5	103.9	149.6	266.0	415.6	598.5	814.7	1,662.6	0.0	245.6	20%	915.9
60	82.2	128.5	185.0	251.8	416.2	621.7	739.9	1,315.4	0.0	257.6	9%	904.9
80	78.7	102.8	160.6	231.2	411.0	520.2	642.3	777.1	1,644.2	294.6	8%	892.2
100	94.1	122.9	192.0	276.5	491.6	622.2	768.1	929.4	1,966.4	352.3	9%	881.0
125	113.0	147.6	230.6	332.1	590.4	747.2	922.5	1,116.2	1,808.1	382.1	17%	868.7
150	131.5	171.8	268.4	386.5	687.2	869.7	1,073.7	1,299.2	2,104.4	444.8	8%	857.6
200	167.5	218.8	341.9	492.4	875.3	1,107.8	1,367.7	1,654.9	1,969.4	516.7	5%	838.0
250	103.2	202.3	264.2	412.8	594.5	1,056.9	1,337.6	1,651.3	1,998.1	485.8	1%	820.7
300	120.4	235.9	308.1	481.4	943.6	1,232.5	1,559.8	1,925.7	2,330.1	598.3	1%	805.0
400	153.1	391.9	612.3	881.8	1,200.2	1,984.0	2,449.4	0.0	0.0	588.4	1%	777.0
500	183.9	360.4	470.7	735.5	1,059.0	1,441.5	1,882.8	2,382.9	0.0	596.0	1%	751.9
600	212.8	306.5	544.9	851.4	1,226.0	1,668.7	2,179.5	0.0	0.0	623.9	1%	728.8
Weighted Average Savings:										**320.0**	therms/yr-trap	

4.2.1.2 Per Unit Energy Savings Methodology - FDD

The following equation, whose variables are described in Table 12, is used to estimate the annual energy savings (AES_{FDD}) for steam trap FDD:

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

The Statewide CASE Team developed this equation 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 four-year average life is assumed, it is not uncommon to see traps that last just a few months or traps in operation for ten or more years. For this analysis, the first repair occurs in the beginning of year four, the second in year eight, 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. “Typical” 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 (i.e. the mode of the orifice size probability distribution for that 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.

$$E_{loss} = W \times h_{fg}$$

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 15 below.

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

Table 15: Factors Used to Calculate Steam Trap FDD Annual Energy Savings

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 18.

While developing the lifecycle cost model, it became evident that the fixed cost of the central steam trap FDD monitoring systems, including 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. An evaluation of the cost effectiveness threshold indicated that FDD system is cost effective when the monitoring system is connected to 25 individual steam traps or more. To simplify compliance and harmonize with the code thresholds that are in place for other process loads, the Statewide CASE Team calculated minimum total combined connected boiler input rating capacity that would serve system with 25 steam traps. The rated capacity is based upon an assumption that under normal conditions (manual inspection of steam traps) a good steam trap maintenance program has around 5 percent ongoing steam leakage as a fraction of boiler capacity. This assumption comes from two studies: (Galitsky, et al. 2008) and (Pacific Northwest National Lab 1999) which describe that even in the presence of good steam trap maintenance program, as assumed in the baseline for these measures, there is still 5-6 percent additional energy savings potential from implementing steam trap FDD. That exception was calculated to be a steam system with a total combined connected boiler input rating capacity of 5.0 MMBtu/hr.

Table 16 presents the analysis performed to develop the total combined connected boiler input rating capacity exception. Appendix G presents the energy savings and cost effectiveness for an entire steam system that just meets the boiler capacity threshold of 5MMBtu/hr.

Table 16: Minimum Total Combined Connected Boiler Input Capacity Exception Analysis

25	FDD Quantity
4	Average steam trap life expectancy
6.25	Average number of failed steam traps per year (25/4)
8,081	Average steam loss of failed trap per year, 100% open trap [therms/yr]
0.667	Rate of Trap Failure in Open Position
0.5	Conservative Assumption on Actual Orifice Size (FEMP FTA - DOE/EE-0193)
16,844	Average steam loss of all failed traps per year [therms/yr]
5%	Baseline Percent loss of Boiler Capacity
336,886	Total Boiler Usage where steam lost to failed traps is 5% of capacity [therms/yr]
6,730	Modeled Operating Hours [hr/yr]
5,000,000	Boiler Input Capacity [Btu/hr]

4.2.1.3 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 four 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 improved trap life, or two and a half failures over the 15 year period of analysis). 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.

The energy savings per strainer are based upon the assumption that steam traps unprotected by strainers will fail on average once every four years, whereas steam traps protected by strainers will fail once every 6 years. Similar to the calculation used for steam trap FDD, once the steam trap fails open, it will on average take six months before the failure is discovered by annual steam trap inspection. It should be noted that this is the annual savings per strainer. Since protecting steam traps with strainers is good practice and commonly conducted, from stakeholder feedback, it is expected that 80 percent of steam traps are protected by strainers. Therefore, strainers impacted by this proposal represent one fifth of total impacted steam traps.

4.2.2 Statewide Energy Savings Methodology

This proposal recommends that for Title 24, Part 6, steam trap FDD be installed on steam traps in new industrial facilities and new industrial process equipment in existing industrial facilities. The per-unit energy impacts were extrapolated to statewide impacts using nationwide industrial steam use data modified to reflect the California market ((5) 2019) (Energetics, Incorporated 2004). The Statewide CASE Team scaled the national industrial steam use data by the relative population of California compared to the nation. The data was then adjusted by end use to reflect California's mix of industrial end uses, increasing the relative representation of some industries such as food and beverage, while reducing the contribution of others such as alumina processing. From this data, it is estimated that a total of 3,591 million therms per year of natural gas are consumed statewide to generate steam in the industrial sector.

From statewide steam process gas consumption data, the steam energy consumption of new industrial facilities and new industrial process equipment in existing industrial facilities per year was forecasted. An average expected growth rate of 1.796 percent, equal to the average of the 10- and 30-year national industrial production growth rate, was used to determine annual new industrial facility construction and the rate of installation of new industrial process equipment in existing industrial facilities that make use of steam. The analysis supporting the savings presented in this report assumes, based on the industrial production forecast, that new industrial facility and new industrial process equipment in existing industrial facilities end uses account for a (3,591 million therms x 0.01792) = 63 million gross therm increase year over year.

As described above, a good steam trap maintenance program has around five percent ongoing steam leakage as a fraction of boiler capacity, thus the typical amount of steam leaks expected result in an energy consumption of (63 million therms x 0.05) = 3.154 million therms per year. The weighted average energy consumption of leaking steam traps calculated across all sizes and pressure bins came out to 320.0 therms/yr. As a result, the number of steam trap FDD installations triggered by newly installed process equipment equates to (3.51 million therms/yr / 320 therms/yr) = 9,860 traps per year.

For steam trap strainer installation, the quantity of steam traps estimated for the automatic monitoring measure was modified based on stakeholder feedback to better reflect the actual market of new opportunities for savings that would result from implementing the measure. This quantity considers that strainer assembly installation is widely considered a best practice, and in many cases a standard practice. Stakeholder feedback suggested that 80 percent of new process equipment installations are designed with upstream strainers, thus the code change proposal would require that the remaining 20 percent of replaced traps would require strainers for a total of (9,860 x 0.20) = 1,972 strainers installed.

Since the statewide savings and the estimate of number of steam traps is based on the initial estimate of California steam usage, the Statewide CASE Team identified other resources to help validate these figures. Oak Ridge National Laboratory contracted with the consultant Energy and Environmental Analysis in a Characterization of the U.S. Industrial/Commercial Boiler Population. As shown in Figure 7, the Pacific Region (PAC) of the U.S. has approximately 120,000 MMBtu of installed industrial boiler capacity. The Pacific region is made up of Alaska, Washington, Oregon, and California.

California consumed 84 percent of the average industrial gas consumption of the Pacific Region from 2005 to 2019. Taking 84 percent of the boiler capacity, applying a 60 percent load factor to account for boilers not being fully loaded and that some of the capacity is back-up, assuming 6,000/yr operation and an 85 percent combustion efficiency, this yields approximately 4,400 million therms per year of gas is being used to serve industrial boilers. This estimate is relatively close to the 3,591 million therms/yr California industrial steam heating natural gas consumption that was used as the basis of the statewide savings estimate. This indicates that the statewide estimate is validated by the Oak Ridge estimate and because the statewide estimate is lower, the statewide estimates of savings used in the report are perhaps conservative.

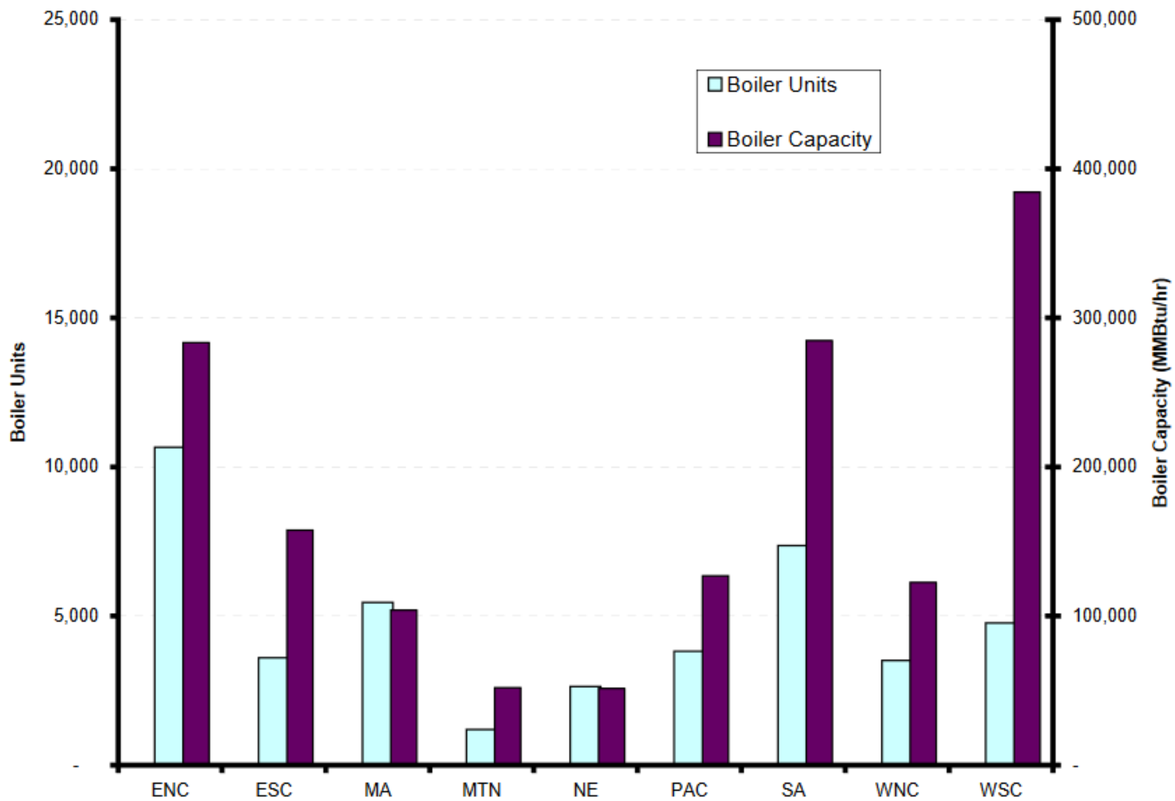

Figure 7: Industrial boiler number and capacity in U.S. by region.

Source: (Energy and Environmental Analysis 2005)

There are approximately 4,000 industrial boilers in the Pacific Region; of these it is estimated that around 3,400 are located in California. One scenario suggested that approximately 109,780 steam traps are replaced due to failure per year in California, which results in an average of 32 steam traps replaced per year per boiler. The same Oak Ridge report found that "[o]verall, the size of the average industrial boiler is 36 MMBtu/hr"; this is about seven times the 5 Million Btu/h threshold proposed for this measure.

Assuming that all steam traps are replaced on an average four-year basis in the scenario referenced above, there are (4 x 32) = 128 total steam traps per 36 MMBtu/h boiler. This indicates that there are 128/36 = 3.55 traps per MMBtu/hr of boiler capacity. This value is close to the 25 total steam traps per 5 MMBtu/h boiler (5 traps per MMBtu/hr) that corresponds to the threshold boiler size.

See Appendix H for assumptions and results of the statewide analysis for alternative code proposals that the Statewide CASE Team is recommending for CALGreen.

4.3 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per unit are presented below. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates.

To determine the final average per-unit savings the Statewide CASE Team used manufacturer data, obtained from targeted stakeholder outreach, that provided the binned operating pressures of the steam traps in their national database. This was assumed to be representative of the California market. The Statewide CASE Team assumed a "common" orifice diameter, as gathered through stakeholder outreach, at each of the binned pressures (refer to Section 4.2.2 above for the full orifice diameter statistical analysis). The savings calculated at each pressure were weighted by the Assuming 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:

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

Table 17 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 17: Energy Savings Per Steam Trap

Inlet Pressure (psig)	Typical Orifice Diameter (inches)	Population of Steam Trap Market at Inlet Pressure (%)	Steam Trap FDD First Year Energy Savings (therms/steam trap-yr)	Strainer Installation First Year Energy Savings (therms/strainer-yr)
15	3/16	9.8%	224	75
30	3/16	10.7%	208	69
45	5/32	20.3%	246	82
60	5/32	8.6%	258	86
80	5/32	7.8%	295	98
100	5/32	8.6%	352	117
125	1/8	17.1%	382	127
150	1/8	7.7%	445	148
200	7/64	4.9%	517	172
250	7/64	0.9%	486	162
300	7/64	0.7%	598	199
400	5/64	0.5%	588	196
500	5/64	1.2%	596	199
600	3/32	1.1%	624	208
Weighted Average Savings (therms/steam trap):			**320**	**107**

For FDD, weighted average per-steam trap unit savings for the first year is expected to be 320 therms/yr. There are no expected direct electricity or electricity demand reductions, the measure does result in embedded electricity savings associated with water savings.

For steam trap strainer installation, weighted average strainer unit savings for the first year is expected to be 107 therms/yr per strainer. There are no expected direct electricity or electricity demand reductions, however the measure does result in embedded electricity savings associated with water savings.

These savings are dependent on the operational behavior of the end-users implementing the measure. Automatic steam trap FDD 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 for steam trap FDD and steam trap strainer installation are presented in Table 18 and Table 19.

Table 18: Steam trap FDD –Energy Savings Per Steam Trap

Gauge Pressure (psig)	Typical 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	3/16	9.8%	73.79	945.7	69,781	224
30	3/16	10.7%	69.60	929.1	64,667	208
45	5/32	20.3%	83.50	915.9	76,475	246
60	5/32	8.6%	88.64	904.9	80,206	258
80	5/32	7.8%	102.83	892.2	91,744	295
100	5/32	8.6%	124.55	881.0	109,725	352
125	1/8	17.1%	136.99	868.7	119,003	382
150	1/8	7.7%	161.50	857.6	138,506	445
200	7/64	4.9%	192.00	838.0	160,896	517
250	7/64	0.9%	184.32	820.7	151,274	486
300	7/64	0.7%	231.44	805.0	186,308	598
400	5/64	0.5%	235.84	777.0	183,244	588
500	5/64	1.2%	246.83	751.9	185,594	596
600	3/32	1.1%	266.60	728.8	194,296	624
Weighted Average Values:				**891.7**	**99,664**	**320**

The energy savings per strainer in Table 19 are based upon a calculation that steam traps unprotected by strainers will fail on average once every four years whereas steam traps protected by strainers will fail once every six years. Similar to the calculation used for steam trap FDD, once the steam trap fails open, on average it takes six months before the failure is discovered by annual steam trap inspection. It should be noted that this is the annual savings per strainer. Since protecting steam traps with strainers is good practice and commonly conducted, from stakeholder feedback, it is expected that 80 percent of new construction steam traps are protected by strainers. Thus, the quantity of strainers impacted by this proposal are 20 percent of the amount of FDD impacted steam traps.

Table 19: Steam Trap Strainer Installation –Energy Savings Per Strainer

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)	Open Trap Energy Loss [Eloss] (Btu/hr-trap)	Annual Energy Savings [ES] (therms/yr-strainer)
15	3/16	9.8%	73.79	945.7	69,781	75
30	3/16	10.7%	69.60	929.1	64,667	69
45	5/32	20.3%	83.50	915.9	76,475	82
60	5/32	8.6%	88.64	904.9	80,206	86
80	5/32	7.8%	102.83	892.2	91,744	98
100	5/32	8.6%	124.55	881.0	109,725	117
125	1/8	17.1%	136.99	868.7	119,003	127
150	1/8	7.7%	161.50	857.6	138,506	148
200	7/64	4.9%	192.00	838.0	160,896	172
250	7/64	0.9%	184.32	820.7	151,274	162
300	7/64	0.7%	231.44	805.0	186,308	199
400	5/64	0.5%	235.84	777.0	183,244	196
500	5/64	1.2%	246.83	751.9	185,594	199
600	3/32	1.1%	266.60	728.8	194,296	208
Weighted Average Values:				**891.7**	**99,664**	**107**

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 based on modifying the 2022 TDV value of 2023 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 2023 PV$20.55/therm, or a levelized value of $1.72/therm.

The proposed code change applies to steam traps serving new industrial facilities and steam traps serving new industrial process equipment in existing industrial facilities.

5.2 Energy Cost Savings Results

The per unit natural gas savings calculated in Table 18 for steam trap FDD and in Table 19 for protecting steam traps with strainers are multiplied by the 2023 PV $20.55/therm 15-year present value adjusted industrial energy rate to yield the energy cost savings per steam trap being monitored and the energy cost savings resulting from protected steam traps with strainers per strainer. This table includes results from this calculation for each pressure bin, while the last row provides the market weighted average savings per steam trap monitored and per strainer.

Table 20: Steam trap FDD and Strainer Annual Energy Savings and Energy Cost Savings Over 15-Year Period of Analysis by Steam Pressure Bin

Gauge Pressure (psig)	Typical Orifice Diameter (in)	Market Share of Pressure Bin (%)	Annual Energy Savings (therms /yr-trap)	TDV Energy Cost Savings Over 15-year Period of Analysis (2023 PV$ /steam trap)	Annual Energy Savings (therms/yr - strainer)	TDV Energy Cost Savings Over 15-year Period of Analysis (2023 PV$/strainer)
15	3/16	9.8%	224	$4,604	75	$1,535
30	3/16	10.7%	208	$4,267	69	$1,422
45	5/32	20.3%	246	$5,046	82	$1,682
60	5/32	8.6%	258	$5,292	86	$1,764
80	5/32	7.8%	295	$6,054	98	$2,018
100	5/32	8.6%	352	$7,240	117	$2,413
125	1/8	17.1%	382	$7,852	127	$2,617
150	1/8	7.7%	445	$9,139	148	$3,046
200	7/64	4.9%	517	$10,616	172	$3,539
250	7/64	0.9%	486	$9,982	162	$3,327
300	7/64	0.7%	598	$12,293	199	$4,098
400	5/64	0.5%	588	$12,091	196	$4,030
500	5/64	1.2%	596	$12,246	199	$4,082
600	3/32	1.1%	624	$12,820	208	$4,273
Weighted Average Values:			**320**	**$6,576**	**107**	**$2,192**

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 21. This weighted savings is based on the pressure bin distribution that is further described in Section 4.2.1. Appendix F contains the nominal analysis.

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

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 FDD	All	N/A	$6,576	$6,576
Steam Trap Strainer Installation	All	N/A	$2,192	$2,192

5.3 Incremental First Cost

Incremental first cost is the initial cost to adopt more efficient equipment or building practices when compared to the cost of an equivalent baseline project. Therefore, it was important that the Statewide CASE Team consider first costs in evaluating overall measure cost effectiveness. Incremental first costs are based on data available today and can change over time as markets evolve and professionals become familiar with new technology and building practices.

For steam trap FDD, 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 steam trap at a minimum, 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.

Table 22: Steam Trap FDD - 2023 PV First Costs – Per Steam Trap

Cost Element	Cost (2023 PV$)	Year Cost is Incurred
Sensor	$955.47	0
Sensor Installation Labor	$95.55	0
Gateway ($2,500, per 25 sensors)	$100.00	0
Gateway Installation Labor ($200, per 25 sensors)	$8.00	0
Building Permit (Permit per Sensor)	$95.55	0
Manual Trap Assessment Savings (per Trap)	$(19.42)	0
Central Monitoring Platform (per Sensor)	$19.42	0
Total Incremental First Cost	**$1,254.57**	

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 twenty-five-sensor system, corresponding to the 5 MMBu system threshold, when accounting for the cost of the gateway and 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 that 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. As the measure is applicable to new industrial facilities and steam traps serving new industrial process equipment in existing industrial facilities, the additional labor cost for implementation of the strainer and blow-off valve 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 ($)	Integral strainer cost ($)	Steam Trap Mass Flow (lbs/hr)	Steam Trap Estimated Cost
15	274	3/16	0.75	1	150	9.81%	$445	$111	25	$330
30	274	3/16	0.75	1	150	10.74%	$445	$111	38	$330
45	292	5/32	0.75	1	150	20.29%	$445	$111	35	$385
60	307	5/32	0.5	0.75	150	8.62%	$420	$105	44	$365
80	324	5/32	0.75	1	150	7.82%	$445	$111	56	$395
100	338	5/32	0.75	1	150	8.62%	$445	$111	68	$395
125	353	1/8	0.75	1	150	17.11%	$445	$111	53	$395
150	366	1/8	0.75	1	150	7.69%	$445	$111	62	$360
200	388	7/64	0.5	0.75	300	4.91%	$1,082	$271	62	$400
250	406	7/64	0.5	0.75	300	0.93%	$1,082	$271	77	$400
300	422	7/64	0.5	0.75	300	0.66%	$1,082	$271	91	$400
400	448	5/64	0.5	0.75	300	0.53%	$1,082	$271	61	$400
500	470	5/64	0.5	0.75	400	1.19%	$1,239	$310	76	$450
600	489	3/32	0.5	0.75	400	1.06%	$1,239	$310	131	$450
						Weighted Averages	$505.52	$126.38	49	$375.92

Code compliance for steam trap strainer installation is achieved through either the installation of a strainer and blow-off valve within three feet of a downstream steam trap or through the installation of a steam trap with integral strainer and blow-off valve. The Statewide CASE Team investigated and specifically sought additional data sources with the release of the Draft CASE Report to determine both the current prevalence of steam traps installed with integral strainers and 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. The cost modeling presented in the Final CASE Report is based on a stand-alone strainer and blow-off valve configuration at 75 percent occurrence and integral strainer configuration at a 25 percent occurrence. The integral strainer and blow-off valve configuration would be substantially less costly than the stand-alone configuration.

The Statewide CASE Team also specifically sought feedback pertaining to integral strainer prevalence and incremental strainer costs in more detail during stakeholder reviews. Resultant stakeholder feedback indicates that the incremental cost of a steam trap with integral strainer and blow off would be approximately 25 percent of the stand-alone strainer cost, reflecting an incremental cost of approximately $126 for an integral strainer.

This consideration of integral strainer cost, market share, consequent updates to cost effectiveness supported application of the proposed requirements to systems operating at greater than 15 psig. This would affect more steam traps, meeting cost effectiveness, than the 30 psig threshold presented in the Draft CASE Report.

Table 24: Steam Trap Strainer Installation - 2023 PV First Costs – Per Strainer

Cost Element	**Cost (2023 PV$)**	**Year Cost is Incurred**
Strainer (Weighted Average)	$410.74	0
-Stand Alone Strainer Cost (75% Market Presence)	$505.52	0
-Integral Strainer Incremental Cost (25% Market Presence)	$126.38	0
Installation Labor	$75.00	0
Total Incremental First Cost	**$485.74**	0

Based on data from available cost databases and stakeholder interviews, equipment and labor cost estimates were developed. The incremental time required to install the strainer is estimated to be one-half hour duration per strainer installed. Pricing for strainers ranges from the relatively inexpensive to the very expensive, based on application, material and pressure. For purposes of cost modeling flanged carbon steel stand-alone strainers were used in the absence of integral strainers as this type and style are most common in general process applications.

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 real (inflation adjusted) 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 n^{th} 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 FDD, 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 FDD are presented in Table 25.

Table 25: Steam Trap FDD - 2023 PV Incremental Maintenance and Replacement Costs – Per Steam Trap

Cost Element	Cost (2023 PV$)	Year Cost is Incurred
Sensor	$710.96	10
Sensor Installation Labor	$71.10	10
Gateway ($2,500, one per 30 sensors)	$74.41	10
Gateway Installation Labor	$5.95	10
Building Permit (Permit per Sensor)	$71.10	10
Manual Trap Assessment Savings (per Trap)	$(227.73)	1-15
Central Monitoring Platform Service ($187/ea)	$227.73	1-15
Battery ($100)	$323.11	3, 6, 9, 12, 15
Total Incremental Maintenance and Equipment Cost	**$1,256.62**	

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. Results from the incremental maintenance cost analysis for steam trap strainer installation are presented in Table 26.

Table 26: Steam Trap Strainer Installation - 2023 PV Incremental Maintenance and Replacement Costs – Per Strainer

Cost Element	Recurrent Cost	Cost (2023 PV$)	Year Cost is Incurred
Strainer	$410.74	$333.97	7
Strainer Labor	$75.00	$60.98	7
Steam Trap Replacement (4 yr interval)	$(375.92)	$(894.42)	4, 8, 12
Steam Trap Replacement Labor (4 yr interval)	$(75.00)	$(178.45)	4, 8, 12
Steam Trap Replacement (6yr interval)	$375.92	$578.49	6, 12
Steam Trap Replacement Labor (6 yr interval)	$75.00	$115.41	6, 12
Maintenance ($8.75/ea)	$8.75	$97.34	1-15
Total Incremental Maintenance and Equipment Cost		**$113.33**	

5.5 Cost Effectiveness

5.5.1 Results of Statewide CASE Team Cost Effectiveness Analysis

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.

As discussed in Section 5.3, the Statewide CASE Team gathered additional details on integral strainer and blow-off valve configuration prevalence and incremental cost.

Table 27 shows the cost effectiveness of the FDD and strainer measures per unit, steam trap and strainer respectively. The integral strainer analysis proved to be less costly than the stand-alone configuration and improved the weighted B/C ratio across all steam pressures to 3.66. Additionally, this consideration of integral strainer cost and market share and consequent updates to cost effectiveness resulted in the code change proposal applying to systems operating at greater than 15 psig, rather than the 30 psig and higher threshold previously proposed.

Table 27: Steam Trap FDD and Strainer 15-Year Cost-Effectiveness by Steam Pressure Bin

Gauge Pressure (psig)	Market Share of Pressure Bin (%)	Stem Trap FDD Energy Cost Savings over 15-Year Period of Analysis (PV$/ trap)	Steam Trap FDD Incremental Cost Over 15-year Period of Analysis (2023 PV$/trap)	Steam Trap FDD B/C Ratio	Strainer Energy Cost Savings over 15-Year Period of Analysis (2023 PV$/ strainer)	Strainer Incremental Cost Over 15-year Period of Analysis (2023 PV$/strainer)	Strainer B/C Ratio
15	9.8%	$4,604	$2,511	1.83	$1,535	$549	2.80
30	10.7%	$4,267	$2,511	1.70	$1,422	$549	2.59
45	20.3%	$5,046	$2,511	2.01	$1,682	$502	3.35
60	8.6%	$5,292	$2,511	2.11	$1,764	$482	3.66
80	7.8%	$6,054	$2,511	2.41	$2,018	$494	4.09
100	8.6%	$7,240	$2,511	2.88	$2,413	$494	4.89
125	17.1%	$7,852	$2,511	3.13	$2,617	$494	5.30
150	7.7%	$9,139	$2,511	3.64	$3,046	$523	5.82
200	4.9%	$10,616	$2,511	4.23	$3,539	$1,428	2.48
250	0.9%	$9,982	$2,511	3.97	$3,327	$1,428	2.33
300	0.7%	$12,293	$2,511	4.90	$4,098	$1,428	2.87
400	0.5%	$12,091	$2,511	4.81	$4,030	$1,428	2.82
500	1.2%	$12,246	$2,511	4.88	$4,082	$1,617	2.52
600	1.1%	$12,820	$2,511	5.11	$4,273	$1,617	2.64
Weighted Average Values:		**$6,576**	**$2,511**	**2.62**	**$2,192**	**$599**	**3.66**

Results of the per-unit cost-effectiveness analyses are presented in Table 28. For steam trap FDD and strainer installation, the proposed measures save money over the 15-year period of analysis relative to the existing conditions. The proposed code change is cost effective with a B/C ratio of 2.62 for steam trap FDD and 3.66 for strainer installation.

Table 28: 15-Year Cost-Effectiveness Summary

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 FDD	$6,576	$2,511	2.62
Steam Trap Strainer Installation	$2,192	$599	3.66

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). 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.

5.5.2 Comparison of CASE Analysis to Existing Studies

This section presents studies and industry literature that investigate FDD savings. Results of multiple system reviews support that FDD installation results in real savings. Table 29 summarizes the annual cost savings per steam trap from three case studies where steam trap fault detection and diagnosis (FDD) were installed.

Table 29: Previous Reported Energy Cost Savings for Steam Trap FDD

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

Two case studies sponsored by Armstrong International show the vast amount of savings that can result from steam trap FDD, claiming that “of the total energy consumed by industry, approximately 50% is used to generate steam”. In the first case study, a Canadian refinery saved more than $1 million per year after a steam trap testing and replacement effort. In the second case study, a plastic laminating facility in Ohio tested and upgraded its steam traps that resulted in $20,000 in savings a month. Ultimately monitoring helps make the system more efficient in a time and cost-efficient manner (Bloss, Bockwinkel and Rivers n.d.).

In a 2010 Save Energy Now presentation sponsored by the U.S. Department of Energy, the author notes that even the smallest steam trap which fails can waste $8,000 per year. On average, 15-20 percent of steam traps fail per year and are only manually inspected once in that year. With steam trap FDD, failures are detected earlier, resulting in improved performance and cost savings for the operator (Fuhr n.d.). This steam loss, due to the need for more user-heavy maintenance and corresponding higher likelihood for human error in not detecting steam trap failures, could be mitigated with the installation of a steam trap FDD system.

In an example given by Everactive, one particular customer with 200 steam traps, an average PSI of 15, steam cost of $20/1,000 lbs, a ¼ inch orifice size, and cold failure of $50,000, the net annual savings from the Everactive devices was $128,241 and 1,312 tons of CO2 savings (Everactive 2020). In a separate report, Everactive notes that 20 percent of a facility's central boiler plant's steam can already be lost from working steam traps and malfunctioning steam traps can only exacerbate those losses through equipment downtime, lost productivity, equipment repair time, and further energy losses. By continuous monitoring of steam traps, repair times would improve and the company would save both energy costs and CO2 emissions that steam traps help reduce (Everactive 2019).

By utilizing a wireless system, a major food manufacturer was able to save energy and maintenance hours by remotely identifying steam trap failures that otherwise would have gone unchecked and caused larger energy losses. They determined that "by installing wireless acoustic transmitters, the plant will prevent steam loss with early detection of steam trap failure… and free up maintenance to focus their time and attention on things that need to be fixed" (Emerson 2020). A separate study investigated the impact in another industry, at a petrochemical company in South Africa. The previous manual process could "take up to 3 to 4 weeks before a faulty steam trap can be detected," while the installation of the wireless system provided online alerts to the maintenance department and reduced manual inspections to save significantly in maintenance costs (Emerson 2017).

Another end user, Genentech, had previously relied on manual steam trap maintenance and monitoring and estimated costing hundreds of thousands of dollars annually from steam loss. They installed wireless steam trap monitors on 56 steam traps and estimated significant savings of $53,000 from the resultant early detection (Stubbs, Implementing Performance Based maintenance, Saving Energy and Improving Uptime 2009). In another industry, Oak Ridge National Laboratory replaced manual inspections with remote steam trap FDD along the 12 miles of steam lines and calculated hundreds of thousands of dollars in savings along with increased safety for their maintenance team (Oak Ridge National Laboratory 2010).

The University of Minnesota published a 2006 case study detailing steam trap FDD success. The Metropolitan Airports Commission (MAC) had over 700 traps in its steam system and previously did not know whether a trap failed. After installing remote monitoring sensors, they were able to remotely determine the status and location of failed steam traps to save time. They also conducted economic analyses to show that “the cost of testing steam traps and repairing and replacing them is generally less than a one year payback” (University of Minnesota 2006).

6. First-Year Statewide Impacts

6.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for steam traps serving new industrial facilities and steam traps serving new industrial process equipment in existing industrial facilities 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 Section 4 as are the Statewide CASE Team's assumptions to calculate the savings.

The Title 24, Part 6 proposal covers all steam traps on large (connected capacity greater than 5 MMBtu/hr), high pressure (greater than 15 psig) steam systems serving newly installed process equipment. This includes equipment on new industrial facilities and steam traps serving new industrial process equipment in existing industrial facilities. With the assumption of a new industrial facilities and steam traps serving new industrial process equipment in existing industrial facilities growth rate of 1.796 percent, resulting in annual estimated statewide impact of 9,860 steam traps per year being covered and required to have steam trap FDD. Strainers are also required on these steam traps being outfitted with FDD. From discussion with industry stakeholders, protecting steam traps with strainers is good practice and it is estimated that 80 percent of new industrial facilities and steam traps serving new industrial process equipment in existing industrial facilities are already being protected by stand-alone strainers or strainers that are integral to the steam trap. The remaining 20 percent of steam traps or 1,972 steam traps per year would be required to add strainers.

The first-year energy impacts represent the first-year annual savings from all industrial steam users completed in 2023. The impacts of this measure are high due to the high energy losses due to steam trap failure in industrial factories. The 15-year energy cost savings represent the discounted energy cost savings over the entire 15-year analysis period for one year's permitted projects. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

The statewide natural gas savings are the per unit savings in Table 18 and Table 19, multiplied by the number of steam traps and strainers impacted during the first after these proposed Part 6 requirements take effect. The statewide electricity savings results from the embedded energy in the water savings resulting from this measure as calculated in Table 32 in the Statewide Water Use Impacts section. The measure does not directly reduce electric energy consumption, but the reduction of steam loss to the surrounding environment yields significant water savings as further described in Section

6.3. Those water savings have an embedded electricity consumption which is represented in the “First-Year Electricity Savings” column below.

Table 30 presents first-year statewide savings when steam trap FDD is implemented on new industrial facilities and steam traps serving new industrial process equipment in existing industrial facilities for the Part 6 proposal. See Appendix H for results of the statewide analysis for alternative code proposals that the Statewide CASE Team is recommending for CALGreen.

Table 30: First Year[a] Statewide Energy and Energy Cost Impacts –Steam Trap FDD

Submeasures	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)
Steam Trap FDD	**0.064**	**N/A**	**3.156**	**$64.84**
New Construction	0.064	N/A	3.156	$64.84
Alterations	N/A	N/A	N/A	N/A
Strainers	**0.004**	**N/A**	**0.210**	**$4.32**
New Construction	0.004	N/A	0.210	$4.32
Alterations	N/A	N/A	N/A	N/A
Option A Total	**0.068**	**N/A**	**3.366**	**$69.16**

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

b. First-year electricity savings are embedded electricity savings resulting from water 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.

6.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated 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 B for additional details on the methodology used to calculate GHG emissions. In short, this analysis uses a natural gas emission factor of 5,454.4 metric tons per million therms.

Table 31 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 18,359 metric tons of carbon dioxide equivalents (metric tons CO2e) would be avoided.

Table 31: 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 FDD	0.064	15.344	3.156	17,211.9	17,227.3
Steam Trap Strainer Installation	0.004	1.023	0.210	1,147.5	1,148.5
Option A TOTAL	**0.068**	**16.367**	**3.366**	**18,359.4**	**18,375.8**

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 892 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 A additional information on the embedded electricity savings estimates.

Water and embedded electricity savings per steam trap for steam trap FDD and strainer installation are presented in Table 32. The energy savings per strainer are based upon a calculation that steam traps unprotected by strainers will fail on average once every four years whereas steam traps protected by strainers will fail once every 6 years. Similar to the calculation used for steam trap FDD, once the steam trap fails open, it will on average take six months before the failure is discovered by annual steam trap inspection. It should be noted that this is the annual savings per strainer. Since protecting steam traps with strainers is good practice and, according to stakeholder feedback, commonly conducted, it is expected that 80 percent of new industrial facilities and steam traps serving new industrial process equipment in existing industrial facilities includes protecting steam traps by installation of a new strainers. Therefore, strainers impacted by Part 6 are twenty percent of impacted steam traps (for Part 11 as referenced in the Report Appendices that increases to 60 percent of steam traps.)

Table 32: Impacts on Water Use and Embedded Electricity in Water

Impacts	On-Site Indoor Water Savings (gallons/yr)	On-Site Outdoor Water Savings (gallons/yr)	Embedded Electricity Savings (kWh/yr)
Per Automatic Steam Trap FDD Impacts	N/A	1,786	6.37
Per Strainer Impacts	N/A	595	2.12
First-Year Statewide Impacts	N/A	19.098,000	68,000

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 33 presents the material impact estimates associated with FDD systems and strainers on a per-unit basis and annually statewide.

Table 33: 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 FDD System Impacts	Mercury	NC	N/A	N/A
	Lead	NC	N/A	N/A
	Copper	NC	N/A	N/A
	Steel	I	2	19,720
	Plastic	I	1	9,860
	Aluminum	I	1	9,860
	Rubber	I	0.25	2,465
Strainer Impacts	Steel	I	2.5	4,930

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 including: 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. "Would" is mandatory and "may" is permissive.

(b) **Definitions.** Terms, phrases, words and their derivatives in Part 6 would be defined as specified in Section 100.1. Terms, phrases, words and their derivatives not found in Section 100.1 would 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 would 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 would comply with the applicable requirements of Sections 120.6(a) through 120.6(j).

…

120.6(j) Mandatory Requirements for Steam Traps. Steam traps in new industrial facilities and steam traps serving new industrial process equipment in existing industrial facilities where the installed steam trap operating pressure is greater than 15 psig and the total combined connected boiler input rating is greater than 5 Million Btu/hr, the steam traps shall conform to the following:

1. **Central Steam Trap FDD 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 8-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.

2. 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(j)2 of this section.

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(j), the equipment and systems would be certified as meeting the Acceptance Requirement for Code Compliance, as specified by the Reference Nonresidential Appendix NA7. A Certificate of Acceptance would be submitted to the enforcement agency that certifies that the equipment and systems meet the acceptance requirements specified in NA7.21.

7.3 Reference Appendices

NA7.21 Steam Trap Fault Detection Acceptance Tests

NA7.21.1 Construction Inspection

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

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

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

(c) 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.

NA7.21.2 Functional Testing

For steam systems with up to seven (7) steam traps required to have fault detection in accordance with Section 120.6(j), all steam traps would be tested. For steam systems with more than seven (7) steam traps; sampling would 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 would 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 would make mention of a new compliance process for covered processes in Section 13.4.4 and Table 13-1.0 would 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(j) 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(j).

Compliance document NRCI-PRC-01-E would need to be revised to include Section 120.6(j) 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(j).

New compliance document NRCA-PRC-17-F would need to be created and added to Appendix A Compliance Documents. The new document certifies that the FDD systems and steam trap strainer installations meet the new acceptance requirements specified in NA7.21.

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Appendix A: 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 34. 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 34: 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 34) 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 35). The energy intensity values presented in Table 34 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 35: 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 B: 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). To demonstrate the cost savings of avoided GHG emissions, the Statewide CASE Team disaggregated the value of avoided GHG emissions from the other economic impacts. The authors used the same monetary values that are used in the TDV factors – $106.20 per metric ton CO_2e.

Water Use and Water Quality Impacts Methodology

There are no impacts to water quality or water use.

Appendix C: 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 D: 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 36 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 36 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 E 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 36: 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.

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
System Designer	• Identify relevant requirements pertaining to new mandatory covered process- identify applicability of 120.6(j). • 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.	• Marginal increase in design cost and timeline. • Require understanding of energy code impact on steam systems which has not previously been impacted.	• Steam system and industrial process equipment design firms should be provided training on the energy code adoption. • Steam system and industrial process equipment design firms should be provided training on compliance requirements and compliance documentation.
Plans Examiner	• Checks submitted building design plans are in compliance with Section 120.6(j) 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 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(j).

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
Facility Manager	Oversee industrial process equipment subject to 120.6(j) effectively meet compliance requirements.	Quickly and effectively comply with Section 120.6(j) when code is triggered.	Time commitment to support construction and functional acceptance test requirements.	• Provide education that steam trap systems are potentially subject to 120.6(j). • Provide education for streamlined compliance.
Installer	• Review new design requirements components and equipment specifications subject to Section 120.6(j). • Install equipment as specified in the approved design documents. • Completes and submits NRCA-PRC-01-E,NRCA-PRC-17-F and/or NRCI-PRC-01-E for steam traps serving industrial process equipment as needed per Section NA7.16.	• 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 and accurately complete and submit compliance documents.	• Steam traps serving industrial process equipment would require additional review of design plans. • Installer could act as Field Technician pertaining to certification process requirements.	• 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.

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
Field Technician	• Complete NA7.16 compliance tests. • Submit NRCA-PRC-01-E, NRCA-PRC-17-F and/or NRCI-PRC-01-E 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 E: 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 Final 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 37: 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[11] (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, and recorded outcomes of live attendee polls to evaluate stakeholder participation and support.

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

Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email and phone with numerous stakeholders when developing this report. Table 38 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 38: 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 FDD (1)	Steam Trap and Automatic Steam Trap FDD Company (1)	(F. (1), 10252019 - FDD (1) – ST_FDD Manufacturer (1) 2019)
Automatic Steam Trap FDD (2)	Automatic Steam Trap FDD Company (2)	(F. (2), 10292019 - FDD (2) –FDD Manufacturer (2) 2019)
Subject Matter Expert (3)	Manual Steam Trap Assessment Company (3)	(S. (3) 2019)
Automatic Steam Trap FDD (3)	Automatic Steam Trap FDD Company (3)	(F. (3) 2019)
Automatic Steam Trap FDD (4)	Steam Trap and Automatic Steam Trap FDD Company (4)	(F. (4) 2019)
Subject Matter Expert (4)	Distributor, Vendor, Designer (1)	(S. (4) 2019)
Automatic Steam Trap FDD (1)	Steam Trap and Automatic Steam Trap FDD Company (1)	(F. (1), 02112020 - FDD (1) – ST_FDD Manufacturer (1) 2020)
Automatic Steam Trap FDD (2)	Automatic Steam Trap FDD Company (2)	(F. (2), 02112020 - FDD (2) – FDD Manufacturer (2) 2020)
California End User (2)	California Steam End User Company (2)	(E. (2) 2020)

Appendix F: Nominal Energy Cost Savings

In Section 5.2, Table 21, 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 they are in the TDV analysis, but the time value of money is not included so the results are not discounted.

Measure	Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
Steam Trap FDD	All	N/A	$13,481	$13,481
Steam Trap Strainer Installation	All	N/A	$4,494	$4,494

Appendix G: Energy Savings and Costs per 5MMBtu/hr Steam Boiler Capacity

The intention of this appendix is to provide detail on what the energy savings, cost savings, and cost-effectiveness values would be for a system which meets the minimum boiler capacity size threshold (5MMBTY/hr). The average steam boiler system with 5MMBtu/hr of connected boiler capacity is calculated to have on average 25 steam traps. See results in Table 39 (automatic steam trap FDD) Table 40 (steam trap strainers).

Table 39: Cost Effectiveness at Each Pressure Bin – Steam Trap FDD

Gauge Pressure (psig)	Market Presence	Annual Energy Savings (therms/yr-trap)	TDV Energy Cost Savings Over 15-year Period of Analysis Present (2023 PV$/trap)	Incremental Cost over 15-year Period of Analysis (2023 PV$/trap)	B/C Ratio
15	10%	5,602	$115,108.69	$62,779.74	1.83
30	11%	5,191	$106,673.16	$62,779.74	1.70
45	20%	6,139	$126,151.77	$62,779.74	2.01
60	9%	6,439	$132,306.61	$62,779.74	2.11
80	8%	7,365	$151,338.85	$62,779.74	2.41
100	9%	8,809	$180,999.57	$62,779.74	2.88
125	17%	9,554	$196,304.64	$62,779.74	3.13
150	8%	11,119	$228,477.12	$62,779.74	3.64
200	5%	12,917	$265,410.71	$62,779.74	4.23
250	1%	12,144	$249,538.64	$62,779.74	3.97
300	1%	14,957	$307,329.57	$62,779.74	4.90
400	1%	14,711	$302,275.47	$62,779.74	4.81
500	1%	14,899	$306,151.72	$62,779.74	4.88
600	1%	15,598	$320,506.54	$62,779.74	5.11
Weighted Average:		**8,001**	**$164,404.23**	**$62,779.74**	**2.62**

Table 40: Cost Effectiveness at Each Pressure Bin – Steam Trap Strainer

Gauge Pressure (psig)	Market Presence	Annual Energy Savings (therms/yr-strainer)	TDV Energy Cost Savings Over 15-year Period of Analysis Present (2023 PV$/strainer)	Incremental Cost over 15-year Period of Analysis (2023 PV$/strainer)	B/C Ratio
15	10%	373	$7,673.91	$2,742.52	2.80
30	11%	346	$7,111.54	$2,742.52	2.59
45	20%	409	$8,410.12	$2,511.40	3.35
60	9%	429	$8,820.44	$2,411.30	3.66
80	8%	491	$10,089.26	$2,469.38	4.09
100	9%	587	$12,066.64	$2,469.38	4.89
125	17%	637	$13,086.98	$2,469.38	5.30
150	8%	741	$15,231.81	$2,616.45	5.82
200	5%	861	$17,694.05	$7,140.31	2.48
250	1%	810	$16,635.91	$7,140.31	2.33
300	1%	997	$20,488.64	$7,140.31	2.87
400	1%	981	$20,151.70	$7,140.31	2.82
500	1%	993	$20,410.11	$8,086.62	2.52
600	1%	1,040	$21,367.10	$8,086.62	2.64
Weighted Average:		**533**	**$10,960.28**	**$2,995.34**	**3.66**

Appendix H: Energy, Energy Cost, Water, and GHG Impacts of Alternative Code Change Options

The Statewide CASE Team considered several options to apply the requirements to steam systems in California. Each option described below and in Section 3.2.4 would allow the state to realize the energy and GHG savings along different time horizons:

- Option A: Under this option, the proposed requirements would only apply to new industrial facilities[12] or new processes added to existing facilities.
- Option B: Under this option the proposed requirements would apply to the systems identified in Option A (new facilities or lines) and the portions of existing steam systems that are served by equipment that is replaced at the end of life.
- Option C: Under this option, the proposed requirements would apply to all replacement steam traps.

The Statewide CASE Team considered several options to apply the requirements to steam systems in California. Each option described below and in Section 3.2.4 would allow the state to realize the energy and GHG savings along different time horizons:

- Option A (smallest scope): Under this option, the proposed requirements would only apply to new industrial facilities or new processes added to existing facilities.
- Option B (moderate scope): Under this option the proposed requirements would apply to the systems identified in Option A (new facilities or lines) and the portions of existing steam systems that are served by equipment that is replaced at the end of life.
- Option C (expansive scope): Under this option, the proposed requirements would apply to all replacement steam traps.

This appendix presents energy, energy cost, GHG, water, and embedded electricity impacts of the three options. Table 41 provides additional detail about the assumptions used to estimate the quantity of steam traps impacted by each option, in a top down approach starting with the overall industrial steam use in the state, adjusted for prevalence of specific industries. For each Option, a different set of assumptions are made based on the triggering event. For example, Option A anticipates implementation of the measure when a new process line, or new factory is built, and so an estimation of anticipated industrial growth is used to evaluate the quantity of traps impacted by the

[12] Section 100.1(b) of Title 24, Part 6 includes the following definition as one of the nonresidential building occupancy types "Industrial/Manufacturing Facility Building is a building with building floor area used for performing a craft, assembly or manufacturing operation.

proposed trigger. Option A is also the approach described throughout the main body of the report. Option B estimates that industrial process equipment is replaced on average every 20 years (EUL), so the approach considers using amount of steam impacted by replacing five percent of statewide process equipment annually. Finally, Option C estimates the amount of statewide steam impacted by steam traps failing every four years on average.

For the analysis presented in this appendix, it is assumed that each option would be adopted statewide, meaning the requirements would apply to all steam systems in the state. As discussed in this report, the Statewide CASE Team recommends that Option B and C be incorporated into CALGreen as voluntary requirements. The CALGreen requirements would become mandatory within a local jurisdictions only if that jurisdiction adopts the CALGreen requirements as a local ordinance. As such, the statewide impacts presented in this appendix are not a reflection of the savings that the state would likely realize if Option B and C are adopted into CALGreen.

Table 41: Trap Quantity Impacted by Each Code Change Option

Value	Description
3,591	Million therms, Annual California Industrial Steam Use
320	Therms, Per unit Steam Trapp FDD energy savings
Option A- New Construction	
1.796%	GDP Annual Growth, Average of previous 10- and 30-year rates, assumed to be the expected rate of new process line and new factory growth
63.0	Million therms, Industrial steam consumption potential for new facilities and new industrial equipment at existing facilities annually
3,154,090	Therms, Energy Savings potential from leaking steam traps (5%)
9,860	Impacted annual Steam Trap FDD quantity at weighted average 320 therms/trap
1,972	Impacted annual Steam Trap Strainer quantity, 20% of impacted traps
Option B- Newly Installed Process Equipment	
20	Process Equipment EUL (years) - Equipment Replacements Trigger
175.6	Million therms, Industrial Steam Use Potential impacted by newly installed industrial process equipment replacements
8,783,319	Therms, Energy Savings potential from leaking steam traps (5%)
27,450	Impacted annual Steam Trap FDD quantity at weighted average 320 therms/trap
5,490	Impacted annual Steam Trap Strainer quantity, 20% of impacted traps
Option C- Steam Trap Replacements	
4	Steam Trap EUL (years) – Steam Trap Replacement Trigger
878.3	Million therms, impacted by steam trap replacements
35,133,276	Therms, Energy Savings potential from leaking steam traps (5%)
109,780	Impacted annual Steam Trap FDD quantity at weighted average 320 therms/trap

65,868	Impacted annual Steam Trap Strainer quantity, 60% of impacted traps

First-Year Statewide Energy and Energy Cost Savings

Table 42: First-Year[a] Statewide Energy and Energy Cost Savings – Option A

Submeasure	First-Year Electricity Savings (GWh)[b]	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (Million Therms)	TDV Energy Savings (million TDV kBtu/yr)	15-Year Present Valued Energy Cost Savings (2023 PV$ Million)	Avoided GHG Emissions (Metric Tons CO2e/yr)	Monetary Value of Avoided GHG Emissions (2023)
Steam Trap FDD							
New Construction	0.064	N/A	3.156	803.05	$64.84	17,227.3	$1,826,093
Alterations	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strainer							
New Construction	0.004	N/A	0.210	53.53	$4.32	1,147.5	$121,470
Alterations	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL	**0.068**	**N/A**	**3.366**	**856.59**	**$69.16**	**18,375.8**	**$1,947,833**

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

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

Table 43: First-Year[a] Statewide Energy and Energy Cost Savings – Option B

Submeasure	First-Year Electricity Savings (GWh)[b]	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (Million Therms)	TDV Energy Savings (million TDV kBtu/yr)	15-Year Present Valued Energy Cost Savings (2023 PV$ Million)	Avoided GHG Emissions (Metric Tons CO2e/yr)	Monetary Value of Avoided GHG Emissions (2023)
Steam Trap FDD							
New Construction	0.178	N/A	8.785	2,235.67	$180.52	47,960.4	$5,083,798
Alterations	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strainer							
New Construction	0.012	N/A	0.586	149.04	$12.03	3,197.4	$338,920
Alterations	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL	**0.190**	**N/A**	**9.371**	**2,384.71**	**$192.55**	**51,157.7**	**$5,422,718**

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

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

Table 44: First-Year[a] Statewide Energy and Energy Cost Savings – Option C

Submeasure	First-Year Electricity Savings (GWh)[b]	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (Million Therms)	TDV Energy Savings (million TDV kBtu/yr)	15-Year Present Valued Energy Cost Savings (2023 PV$ Million)	Avoided GHG Emissions (Metric Tons CO2e/yr)	Monetary Value of Avoided GHG Emissions (2023)
Steam Trap FDD							
New Construction	0.711	N/A	35.134	8,941.03	$721.93	191,806.5	$20,331,488
Alterations	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strainer							
New Construction	0.142	N/A	7.027	1,788.21	$144.39	38,361.3	$4,066,298
Alterations	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL	**0.853**	**N/A**	**42.161**	**10,729.24**	**$866.32**	**230,167.8**	**$24,397,786**

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

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

First-Year Statewide GHG Emissions Impacts

Table 45: First-Year[a] Statewide GHG Emissions Impacts – Option A

Measure	Electricity Savings (GWh/yr)	Reduced GHG Emissions from Electricity Savings[b] (Metric Tons CO2e)	Natural Gas Savings (million therms/yr)	Reduced GHG Emissions from Natural Gas Savings[b] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[b] (Metric Tons CO2e)
Automatic Steam Trap FDD	0.064	15.344	3.156	17,211.9	17,227.3
Steam Trap Strainer Installation	0.004	1.023	0.210	1,147.5	1,148.5
Option A TOTAL	**0.068**	**16.367**	**3.366**	**18,359.4**	**18,375.8**

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.

Table 46: First-Year Statewide GHG Emissions Impacts – Option B

Measure	Electricity Savings (GWh/yr)	Reduced GHG Emissions from Electricity Savings[b] (Metric Tons CO2e)	Natural Gas Savings (million therms/yr)	Reduced GHG Emissions from Natural Gas Savings[b] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[b] (Metric Tons CO2e)
Automatic Steam Trap FDD	0.`78	42.719	8.785	47,917.6	47,960.4
Steam Trap Strainer Installation	0.012	2.848	0.586	3,194.5	3,197.4
Option B TOTAL	**0.190**	**45.566**	**9.371**	**51,112.2**	**51,157.7**

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.

Table 47: First-Year Statewide GHG Emissions Impacts – Option C

Measure	Electricity Savings (GWh/yr)	Reduced GHG Emissions from Electricity Savings[b] (Metric Tons CO2e)	Natural Gas Savings (million therms/yr)	Reduced GHG Emissions from Natural Gas Savings[b] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[b] (Metric Tons CO2e)
Automatic Steam Trap FDD	0.711	170.843	35.134	191,635.7	191,806.5
Steam Trap Strainer Installation	0.142	34.169	7.027	38,327.1	38,361.3
Option C TOTAL	**0.853**	**205.012**	**42.161**	**229,962.8**	**230,167.8**

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.

First-Year Statewide Water and Embedded Electricity Impacts

Table 48: First-Year Statewide Water Use and Embedded Electricity Impacts – Option A

Measure	On-Site Indoor Water Savings (gallons/yr)	On-Site Outdoor Water Savings (gallons/yr)	Embedded Electricity Savings (kWh/yr)
Per Automatic Steam Trap FDD Impacts	N/A	1,786	6.37
Per Strainer Impacts	N/A	595	2.12
First-Year Statewide Impacts	N/A	19.098,000	68,000

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.

Table 49: First-Year Statewide Water Use and Embedded Electricity Impacts – Option B

Measure	On-Site Indoor Water Savings (gallons/yr)	On-Site Outdoor Water Savings (gallons/yr)	Embedded Electricity Savings (kWh/yr)
Per Automatic Steam Trap FDD Impacts	N/A	1,786	6.37
Per Strainer Impacts	N/A	595	2.12
First-Year Statewide Impacts	N/A	53,168,000	190,000

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.

Table 50: First-Year Statewide Water Use and Embedded Electricity Impacts – Option C

Measure	On-Site Indoor Water Savings (gallons/yr)	On-Site Outdoor Water Savings (gallons/yr)	Embedded Electricity Savings (kWh/yr)
Per Automatic Steam Trap FDD Impacts	N/A	1,786	6.37
Per Strainer Impacts	N/A	595	2.12
First-Year Statewide Impacts	N/A	239,213,000	853,000

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.

Appendix I: Mark-up Language for CALGreen

This section contains sample code language that could be adopted into the voluntary section the CALGreen. This sample language would not be required until a local jurisdiction adopted this section into their local regulations. Once adopted into the energy regulations of the local jurisdiction, the requirement would be mandatory for industrial facilities located in the local jurisdiction.

Section A5.214.1 represents Option C in the CASE Report and would apply to all steam traps that are newly installed or replaced.

Section A5.214.2 represents Option B in the CASE Report and would apply to all steam traps that are serving newly replaced industrial process equipment.

This proposal would modify the following sections of Title 24, Part 11 as shown below.

CHAPTER 2 – DEFINITIONS

Definitions: **Recommends new or revised definitions for the following terms:**

- The purpose of the change to this section is to add a definition for the term "steam trap operating pressure" — the steam pressure entering the steam trap during normal design operating conditions.

SECTION A5.201.2 – DEFINITIONS

Definitions: **Recommends new or revised definitions for the following terms:**

- Steam trap operating pressure.

SECTION A5.214 – COVERED PROCESS EFFICIENCY

- The purpose of the proposed change to this section is to include new requirements for steam traps. 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 15 psig and with boiler capacity greater than 5.0 MMBtu/hr.

CHAPTER 2

DEFINITIONS

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

APPENDIX A5

Division A5.2 – ENERGY EFFICIENCY

SECTION A5.201

GENERAL

A5.201.1 Scope. For the purposes of mandatory energy efficiency standards in this code, the California Energy Commission will continue to adopt mandatory standards. It is the intent of these voluntary provisions to encourage local jurisdictions through codification to achieve exemplary performance in the area of building energy efficiency. Local jurisdictions adopting these voluntary provisions as mandatory local energy efficiency standards would submit the required application and receive the required approval of the California Energy Commission in compliance with Title 24, Part 1, Section 10-106, prior to enforcement. Once approval is granted by the Energy Commission, local jurisdictions would file an ordinance expressly marking the local modifications along with findings and receive the required acceptance from the California Building Standards Commission in compliance with Section 101.7 of this code, prior to enforcement (Title 24, Part 1, Section 10-106 is available at http://www.energy.ca.gov/title24/2016standards/).

SECTION A5.202

DEFINITIONS

A5.202.1 Definitions. The following terms are defined in Chapter 2.

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STEAM TRAP OPERATING PRESSURE

SECTION A5.214

COVERED PROCESS EFFICIENCY

A5.214.1 Industrial Steam Traps Replacements. Steam traps serving industrial processes with an operating pressure greater than 15 psig and connected to a steam system with a total combined connected boiler input rating greater than 5 Million Btu/hr, shall conform to the requirements of Title 24, Part 6 Section 120.6(j) items 1 through 4.

A5.214.2 Steam Trap Requirements for Steam Traps Serving Newly Installed Process Equipment. Steam traps serving newly installed industrial process equipment with an operating pressure greater than 15 psig and connected to a steam system with a total combined connected boiler input rating greater than 5 Million Btu/hr, shall conform to the requirements of Title 24, Part 6 Section 120.6(j) items 1 through 4.