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Codes and Standards Enhancement (CASE) Initiative

2025 California Energy Code

Process Load Pipe Insulation

Covered Processes
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Final CASE Report

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Executive Summary

This CASE Report presents justifications for code changes to expand existing mandatory pipe insulation requirements to include pipes used in covered processes. Covered processes application can be very energy intensive, so ensuring adequate levels of insulation is critical to maintain high levels of energy efficiency and performance. The proposal highlights the importance of insulating pipes used for covered processes to the same insulation levels required for service water heating, space heating, and space cooling to minimize heat loss and conserve energy.

Currently, Title 24 Part 6 includes insulation requirements for space heating, space cooling, and service water heating covered in Table 120.3-A. This code proposal expands Table 120.3-A to include covered processes applications.

Statewide, the proposed measure is expected to save 2.68 GWh of electricity, and 5.46 million therms of natural gas in the first year, as shown in the table below (and in section 5 of this report). In addition, 30,008 metric tons of carbon dioxide equivalent emissions (metric tons CO_2e) of greenhouse gas (GHG) emissions would be avoided in year one from reduced energy use.

Table 1: Statewide Energy and Energy Cost Impacts — New Construction, Additions, and Alterations

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Million Square Feet)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued Energy Cost Savings (Million 2026 PV$)
All — New Construction and Additions	0.9	0.032	0.00004	0.04	3.88	2.45
All - Alterations	75.34	2.657	0.00314	5.42	491.9	304.76
Total	**76.24**	**2.689**	**0.0032**	**5.46**	**495.82**	**307.2**

The Codes and Standards Enhancement (CASE) Initiative presents recommendations to support the CEC's 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 & 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 would 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 CEC, the state agency that has authority to adopt revisions to Title 24, Part 6. The CEC will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The CEC may revise or reject proposals. See the CEC's 2025 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/2025-building-energy-efficiency.

Proposal Description

Proposed Code Change

The proposed code change would expand the existing mandatory pipe insulation requirements to pipes used for covered processes. With the proposed change, all pipes a half inch and greater in diameter that are used for process heating or cooling, including pipes for chilled water, hot water, and steam, would have to comply with the minimum insulation requirements in Table 120.3-A. The proposal does not recommend revisions to the minimum insulation requirements in Table 120.3-A; rather the proposal would apply the existing minimum insulation requirements to process pipes. The minimum insulation requirements vary depending on whether the pipe is used to deliver heating or cooling, nominal pipe diameter, and the fluid operating temperature range. The proposed requirements would apply to new construction, additions, and alterations. Insulation would be verified with a site inspection.

Table 2: Scope of Code Change Proposal

Type of Requirement	Mandatory
Applicable Climate Zones	All
Modified Section(s) of Title 24, Part 6	100.0(F), 100.1, 120.3, and 141.1
Modified Title 24, Part 6 Appendices	N/A
Would Compliance Software Be Modified	No
Modified Compliance Document(s)	NRCC-PRC-E NRCC-PRC-01-E NRCI-PRC-E

Cost Effectiveness

The proposed code change was found to be cost-effective for all climate zones. The benefit-to-cost ratio over the 30-year period of analysis is 9.0 for new construction and additions and 19.5 for alterations.[1] See Section 6 for the methodology, assumptions, and results of the cost-effectiveness analysis.

Addressing Energy Equity and Environmental Justice

The Statewide CASE Team reviewed published studies that considered how disproportionately impacted populations (DIPs) would be impacted by the proposed measure and considered the impacts of the proposal on DIPs using four criteria: cost, health, disaster preparedness, and comfort. Based on a preliminary review, the proposal is unlikely to have significant impacts on energy equity or environmental justice. That said, DIPs often work in industrial facilities. The presence of pipe insulation often results in less extreme temperatures in working conditions and less likelihood of being burned by inadvertently touching steam piping. Thus, if there is any impact, it is likely positive from a safety perspective. Full details addressing energy equity and environmental justice can be found in Section 2 of this report.

[1] The benefit-to-cost ratio compares the benefits or cost savings to the costs over the 30-year period of analysis. Proposed code changes that have a benefit-to-cost ratio of 1.0 or greater are cost-effective. The larger the benefit-to-cost ratio, the faster the measure pays for itself from energy cost savings.

1. Introduction

The Codes and Standards Enhancement (CASE) Initiative presents recommendations to support the California Energy Commission's (CEC's) 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 would 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 energy-efficient building design practices and technologies.

The Statewide CASE Team submits code change proposals to the CEC, the state agency that has authority to adopt revisions to Title 24, Part 6. The CEC will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The CEC may revise or reject proposals. See the CEC's 2025 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/2025-building-energy-efficiency.

The Statewide CASE Team gathered input from stakeholders to inform the proposal and associated analyses and justifications presented in this report. Stakeholders also provided input on the code compliance and enforcement process. See Appendix F for a summary of stakeholder engagement.

The goal of this CASE Report is to present a cost-effective code change proposal for process load pipe insulation. The report contains pertinent information supporting the code change. When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with industry stakeholders including manufacturers, industry associations, 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 January 31, 2023.

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

- Section 2 – Addressing Energy Equity and Environmental Justice presents the potential impacts of proposed code changes on disproportionately impacted populations (DIPs), as well as a summary of research and engagement methods.

- Section 3 — 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 4 — Market Analysis includes a review of the current market structure. Section 4.2 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 5 — Energy Savings presents the per-unit energy, demand reduction, and Long-term Systemwide Cost (LSC) 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 LSC savings.
- Section 6 — Cost and Cost-Effectiveness presents the lifecycle cost and cost-effectiveness analysis. This includes a discussion of the materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs, i.e., equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.
- Section 7 — First-Year Statewide Impacts presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2025 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. Statewide water consumption impacts are also reported in this section.
- Section 8 — Proposed Revisions to Code Language concludes the report with specific recommendations with ~~strikeout~~ (deletions) and underlined (additions) language for the Standards, Reference Appendices, and Alternative Calculation Method (ACM) Reference Manual. Generalized proposed revisions to sections are included for the Compliance Manual and compliance forms.
- Section 9 — Bibliography presents the resources that the Statewide CASE Team used when developing this report.
- Appendix A: Statewide Savings Methodology presents the methodology and assumptions used to calculate statewide energy impacts.
- Appendix B: Embedded Electricity in Water Methodology presents the methodology and assumptions used to calculate the electricity embedded in water use (e.g., electricity used to draw, move, or treat water) and the energy savings resulting from reduced water use.

- Appendix C: California Building Energy Code Compliance (CBECC) Software Specification presents relevant proposed changes to the compliance software (if any).
- Appendix D: Environmental Analysis presents the methodologies and assumptions used to calculate impacts on GHG emissions and water use and quality.
- Appendix E: Discussion of Impacts of Compliance Process on Market Actors presents how the recommended compliance process could impact identified market actors.
- Appendix F: Summary of Stakeholder Engagement documents the efforts made to engage and collaborate with market actors and experts.
- Appendix G: Energy Cost Savings in Nominal Dollars presents LSC savings over the period of analysis in nominal dollars.

The California IOUs offer free energy code training, tools, and resources for those who need to understand and meet the requirements of Title 24, Part 6. The program recognizes that building codes are one of the most effective pathways to achieve energy savings and GHG reductions from buildings — and that well-informed industry professionals and consumers are key to making codes effective. With that in mind, the California IOUs provide tools and resources to help both those who enforce the code, as well as those who must follow it. Visit EnergyCodeAce.com to learn more and to access content, including a glossary of terms.

2. Addressing Energy Equity and Environmental Justice

2.1 General Equity Impacts

The Statewide CASE Team recognizes, acknowledges, and accounts for a history of prejudice and inequality in disproportionately impacted populations (DIPs) and the role this history plays in the environmental justice issues that persist today. While the term disadvantaged communities (DACs) is often used in the energy industry and state agencies, the Statewide CASE Team chose to use terminology that is more acceptable to and less stigmatizing for those it seeks to describe (DC Fiscal Policy Institute 2017). Similar to the California Public Utilities Commission (CPUC) definition, DIPs refer to the populations throughout California that "most suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes, as well as high incidence of asthma and heart disease" (CPUC n.d.). DIPs also incorporate race, class, and gender since these intersecting identity factors affect how people frame issues, interpret, and experience the world.[2]

Including impacted communities in the decision-making process, ensuring that the benefits and burdens of the energy sector are evenly distributed, and facing the unjust legacies of the past all serve as critical steps to achieving energy equity. Recognizing the importance of engaging DIPs and gathering their input to inform the code change process and proposed measures, the Statewide CASE Team is working to build relationships with community-based organizations (CBOs) to facilitate meaningful engagement. A participatory approach allows individuals to address problems, develop innovative ideas, and bring forth a different perspective. Please reach out to Abed Alkhatib (aalkhatib@energy-solution.com) and Marissa Lerner (mlerner@energy-solution.com) for further engagement.

Energy equity and environmental justice (EEEJ) is a newly emphasized component of the Statewide CASE Team's work and is an evolving dialogue within California and

[2] Environmental disparities have been shown to be associated with unequal harmful environmental exposure correlated with race/ethnicity, gender, and socioeconomic status. For example, chronic diseases, such as respiratory diseases, cardiovascular disease, and cancer, associated with environmental exposure have been shown to occur in higher rates in the LGBTQ+ population than in the cisgender, heterosexual population (Goldsmith and Bell 2021). Socioeconomic inequities, climate, energy, and other inequities are inextricably linked and often mutually reinforcing.

beyond.[3] To minimize the risk of perpetuating inequity, code change proposals are being developed with intentional consideration of the unintended consequences of proposals on DIPs. The Statewide CASE Team identified potential impacts via research and stakeholder input. While the listed potential impacts should be comprehensive, they may not yet be exhaustive. As the Statewide CASE Team continues to build relationships with CBOs, these partnerships will inform and further improve the identification of potential impacts. The Statewide CASE Team is open to additional peer-reviewed studies that contribute to or challenge the information on this topic presented in this report. The Statewide CASE Team is currently continuing outreach with CBOs and EEEJ partners. Results of that outreach as well as a summary of the 2025 code cycle EEEJ activities will be documented in the 2025 EEEJ Summary Report that is expected to be published on title24stakeholders.com by the end of 2023.

2.1.1 Procedural Equity and Stakeholder Engagement

As mentioned, representation from DIPs is crucial to considering factors and potential impacts that may otherwise be missed or misinterpreted. The Statewide CASE Team is committed to engaging with representatives from as many affected communities as possible. This code cycle, the Statewide CASE Team is focused on building relationships with CBOs and representatives of DIPs across California. To achieve this end, the Statewide CASE Team is prioritizing the following activities:

- Identification and outreach to relevant and interested CBOs
- Holding a series of working group meetings to solicit feedback from CBOs on code change proposals
- Developing a 2025 EEEJ Summary Report

In support of these efforts, the Statewide CASE Team is also working to secure funds to provide fair compensation to those who engage with the Statewide CASE Team. While the 2025 code cycle will come to an end, the Statewide CASE Team's EEEJ efforts will continue, as this is not an effort that can be "completed" in a single or even multiple code cycles. In future code cycles, the Statewide CASE Team is committed to furthering relationships with CBOs and inviting feedback on proposed code changes with a goal of

[3] The CEC defines energy equity as "the quality of being fair or just in the availability and distribution of energy programs" (CEC 2018). American Council for an Energy-Efficient Economy (ACEEE) defines energy equity as that which "aims to ensure that disadvantaged communities have equal access to clean energy and are not disproportionately affected by pollution. It requires the fair and just distribution of benefits in the energy system through intentional design of systems, technology, procedures and policies" (ACEEE n.d.). Title 7, Planning and Land Use, of the California Government Code defines environmental justice as "the fair treatment and meaningful involvement of people of all races, cultures, incomes, and national origins, with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies" (State of California n.d.).

engagement with these organizations representing DIPs throughout the code cycle. Several strategies for future code cycles are being considered, including:

- Creating an advisory board of trusted CBOs that may provide consistent feedback on code change proposals throughout the development process
- Establishing a robust compensation structure that enables participation from CBOs and DIPs in the Statewide CASE Team's code development process
- Holding equity-focused stakeholder meetings to solicit feedback on code change proposals that seem more likely to have strong potential impacts

2.1.2 Potential Impacts on DIPs in Nonresidential Buildings

To assess potential inequity of proposals for nonresidential buildings the Statewide CASE Team considered which building types are used by DIPs most frequently and evaluated the allocation of impacts related to the following areas among all populations.

- **Cost:** People historically impacted by poverty and other historic systems of wealth distribution can be affected more severely by the incremental first cost of proposed code changes. Costs can also create an economic burden for DIPs that does not similarly affect other populations. The measure proposed would not have any economic impact or benefit for DIPs. The measure only covers industrial facilities and would have no direct or secondary impact on costs.
- **Health:** Any potential health burdens from proposals could more severely affect DIPs that can have limited access to healthcare and live in areas affected by environmental and other health burdens. Several of the potential negative health impacts from buildings on DIPs are addressed by energy efficiency (Norton 2014., Cluett 2015, Rose 2020). For example, indoor air quality (IAQ) improvements through ventilation or removal of combustion appliances can lessen the incidents of asthma, chronic obstructive pulmonary disease (COPD), and some heart problems. Black and Latinx people are 56 percent and 63 percent more likely to be exposed to dangerous air pollution than white people, respectively . Water heating and building shell improvements can reduce stress levels associated with energy bills by lowering utility bill costs. Electrification can reduce the health consequences resulting from NOx, SO_2, and $PM_{2.5}$. This measure would lower energy use at industrial facilities, and thus have no direct impacts or benefits to health for DIPs.
- **Resiliency:** DIPs are more vulnerable to the negative consequences of natural disasters, extreme temperatures, and weather events due to climate change. Black Americans are 40 percent more likely to currently live in areas with the highest projected increases in extreme heat related mortality rates, compared to other groups (EPA 2021). Similarly, natural disasters affect DIPs differently. Race and wealth affect the ability to evacuate for a natural disaster, as evidenced during Hurricane Harvey wherein White and wealthy residents were overrepresented by 19.8 percent

among evacuees (Deng, et al. 2021). Proposals that improve buildings' resiliency to natural disasters and extreme weather could positively impact DIPs. For example, buildings with more insulation and tighter envelopes can reduce the health impacts of infiltration of poor-quality air, reduce risk of moisture damage and related health impacts (mildew and mold), and help maintain thermal comfort during extreme weather events. This measure would allow for greater resiliency for an industrial facility to weather the temperature swings brought on by climate change, but it would not have any direct impacts for resiliency for residential buildings occupied by DIPs.

- **Comfort:** Thermal comfort and proper lighting are important considerations for any building where people work, though impacts are not proportional across all populations. Thermal comfort can also have serious health effects as heat related illness is on the rise in California. DIPs are at a greater risk for heat illness due in part to socioeconomic factors. From 2005 to 2015 the number of emergency room visits for heat related illness in California rose 67 percent for Black people, 53 percent for Asian-Americans, and 63 percent for Latinx people (Abualsaud, Ostrovskiy and Mahfoud 2019). Studies have shown that not only do the effects of urban heat islands lead to higher mortality during heat waves, but those in large buildings are disproportionately affected (Smargiassi 2008, Laaidi 2012). These residents tend to be the elderly, people of color, and low-income households (Drehobl 2020, Blankenship 2020, IEA 2014). Comfort is not only a nice quality to have in workplaces, schools, etc., but it also has real world health impacts on people's health.

2.2 Specific Impacts of the Proposal

The Statewide CASE Team considered the impacts of the proposal on DIPs using four criteria: cost, health (and safety), disaster preparedness, and comfort. The Statewide CASE Team assessed the potential impacts of the proposed measure and found that most factory workers are classed as low-income (U.S. Bureau of Labor Statistics 2022). The mean annual wage for production workers in California is $42,310, which for the majority of the state's counties is low income (U.S. Bureau of Labor Statistics 2022, U.S. DEPARTMENT OF HUD 2023).The presence of pipe insulation often results in less extreme temperatures, which leads to more comfortable working conditions, especially unconditioned spaces. This measure would thus work to bolster existing OSHA standards (4.3.3) which protects workers against burns or freezes.

Factories and industrial facilities are often located in low-income areas, with one study showing Black people as statistically more likely to live within a mile of a polluting industrial facility than White people (Mohai, et al. 2009). The measure would have a secondary impact at reducing local GHG emissions due to reduced process heating or cooling needs as a result of lower energy losses.

3. Measure Description

3.1 Measure Summary

The current code includes a mandatory requirement that pipes for space heating, service water heating, and space cooling systems be insulated. The proposed code change would expand the existing mandatory pipe insulation requirements so that pipes used for covered processes would also need to be insulated. With the proposed change, all pipes half inch and greater in diameter that are used for process heating or cooling, including pipes for chilled water, hot water, and steam would have to comply with the minimum insulation requirements in Table 120.3-A. The proposal does not recommend revisions to the minimum insulation requirements in Table 120.3-A; rather the proposal would apply the existing minimum insulation requirements to process pipes. The minimum insulation requirements vary depending on whether the pipe is used to deliver heating or cooling, nominal pipe diameter, and the fluid operating temperature range. The proposed requirements would apply to new construction, additions, and alterations. Insulation would be verified through project documentation check, i.e. invoices, and visual inspection confirming the insulation has been installed.

3.2 Proposed Code Change

The sections below summarize how the standards, Reference Appendices, ACM Reference Manuals, compliance manuals, and compliance documents would be modified by the proposed changes.

Summary of changes to the standards:

This proposal would modify the following sections of Title 24, Part 6.

- **Section 100(e)2F.** In describing what is within scope for new buildings, Section 100(e)2 subsection F itemizes the code sections applicable to covered processes. The language is updated to clarify that Section 120.3 — Requirements for Pipe Insulation apply to covered processes.
- **Table 100-A.** Table 100.0-A Application of Standards lists which requirements apply to Section 120.3 is added to the row in the table for the covered processes occupancies. These changes notify building code applicants and building inspectors that there are covered process requirements in Section 120.3 Requirements *for* Pipe Insulation. Section 120.3 is added to both the columns for new construction and alterations. The energy code now requires pipe insulation in new and altered factories and other occupancies where process piping in carrying heated or refrigerated fluids.

- **Section 100.1 Definitions.** The definition for covered process (process, covered) identified that Section 120.3 contains covered process requirements, and that covered process includes “process heating and cooling piping.”
- **Section 120.3 Pipe Insulation**. This mandatory section for minimum pipe insulation levels has its scope expanded to cover process heating system piping, and process cooling system piping. The insulation levels for process heating system piping are the same insulation levels as required for piping carrying hot water or steam for service water heating or space heating. Similarly, the insulation levels for process cooling system piping are the same insulation levels as required for piping carrying chilled water, brines, or refrigerants for space cooling. The levels of insulation required are dependent on the process temperature of the pipes, and can be found in Table 120.3-A.
- **Section 141.1 Process Alterations.** Process piping alterations are added to this section to highlight that when process piping is modified as part of an alteration, the piping shall be insulated to the levels specified in Section 120.3.

3.3 Justification and Background Information

3.3.1 Justification

Pipe insulation helps maintain the temperature of fluids that are transported through the pipes, which is crucial for many industrial processes because the temperature of the fluids can affect the efficiency and effectiveness of the process. Pipe insulation also helps to improve the energy efficiency of the facility by minimizing heat losses in the pipe. Insulation can significantly reduce the amount of energy required to maintain the temperature of fluids or gases in pipes, which can lead to significant energy savings.

The proposed code change recommends minimum levels of pipe insulation for covered processes to reduce energy loss to the atmosphere, while considering cost, impacts on manufacturing practices including maintenance implications (e.g., whether insulation would need to be removed to service equipment).

3.3.2 Background Information

Section 120.3 of 2022 Title 24, Part 6 includes mandatory requirements for pipe insulation that apply to pipes for space cooling, space heating, and service water heating. Table 120.3-A define the minimum insulation requirements that vary by pipe diameter and the fluid operating temperature range. The existing mandatory pipe insulation requirements do not apply to pipes used for covered processes. This proposal would require pipes used for covered processes to meet the minimum pipe insulation requirements that are already defined in Table 120.3-A.

3.4 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance forms would be modified by the proposed change.[4] See Section 8 of this report for detailed proposed revisions to code language.

3.4.1 Specific Purpose and Necessity of Proposed Code Changes

Each proposed change to language in Title 24, Part 1, and Part 6 as well as the reference appendices to Part 6 are described below. See Section 8.2 of this report for marked-up code language.

Section: 100(e)2F

Specific Purpose: The purpose of this change is to ensure that section 120.3 (pipe insulation) is applicable to covered processes.

Necessity: These changes are necessary to ensure all sections of the code applicable to covered processes requirements include section 120.3.

Section: Table 100-A

Specific Purpose: Section 120.3 is added to the row in the table for the covered processes occupancies.

Necessity: changes notify building code applicants and building inspectors that there are covered process requirements in Section 120.3 Requirements for Pipe Insulation.

Section: 100.1 Definitions

Specific Purpose: Add section 120.3 to the definition of covered process.

Necessity: These changes are necessary to ensure all sections of the code applicable to covered processes requirements include section 120.3.

Section: 120.3- Requirements for Pipe Insulation

Specific Purpose: The purpose of this change is to add mandatory requirements for insulation on all process steam pipes, valves, and fittings 0.5 inch and greater in diameter, hot and cold-water pipes 0.5 inches and greater in diameter, and storage tanks. This section would apply to new construction, additions, and alterations.

[4] Visit EnergyCodeAce.com for training, tools, and resources to help people understand existing code requirements.

Section: 141.1 Process Alterations

Specific Purpose: Process piping alterations are added to this section to highlight that when process piping is modified as part of an alteration, the piping shall be insulated to the levels specified in Section 120.3.

Necessity: These changes are necessary to ensure all sections of the code applicable to covered processes requirements include section 120.3.

3.4.2 Specific Purpose and Necessity of Changes to the Nonresidential ACM Reference Manual

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

3.4.3 Summary of Changes to the Nonresidential Compliance Manual

Section: Chapter 10: Covered Process

Specific Purpose: The purpose of this change is to add a subchapter about the proposed mandatory pipe insulation requirements and verification.

Necessity: These changes are necessary to increase energy efficiency by reducing energy losses from hot or cold pipes, valves, and tanks via cost-effective insulation.

3.4.4 Summary of Changes to Compliance Forms

The proposed change would add a new table to these forms for quality pipe insulation installation and field verification documentation.

- 2019-NRCC-PRC-E: Process Systems
- 2019-NRCC-PRC-01-E: Process Systems
- 2022-NRCI-PRC-E Process System

3.5 Regulatory Context

3.5.1 Determination of Inconsistency or Incompatibility with Existing State Laws and Regulations

Title 24, Part 6 Section 120.3 requires insulation on all pipes for space cooling systems, space heating, and service water-heating systems. The minimum insulation requirements are defined in Table 120.3-A; thickness (or R-value) and conductivity varies depending on the pipe diameter and the fluid operating temperature.

The California Code of Regulations, Title 8 — Industrial Relations includes safety requirements for industrial pipe insulation to protect against burns. This requirement does not specify minimum insulation thicknesses. This proposal, which would establish minimum insulation requirements to improve energy efficiency, does not contradict with the requirements in Title 8. Section 3308 states:

> Pipes or other exposed surfaces having an external surface temperature of 140 degrees F (60 degrees C) or higher and located within seven feet measured vertically from floor or working level or within 15 inches measured horizontally from stairways, ramps or fixed ladders shall be covered with a thermal insulating material or otherwise guarded against contact. This order does not apply to operations where the nature of the work or the size of the parts makes guarding or insulating impracticable.

3.5.2 Duplication or Conflicts with Federal Laws and Regulations

There are no relevant federal laws or regulations.

3.5.3 Difference From Existing Model Codes and Industry Standards

ASHRAE Standard 90.1-2022 Table 6.8.3-1 requirements closely match Title 24, Part 6 Table 120.3-A The 2021 IECC TABLE C403.12.3 also has similar insulation requirements but it is limited to service water heating and piping for space heating and cooling systems.

3.6 Compliance and Enforcement

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

The compliance verification activities related to this measure that need to occur during each phase of the project are described below:

- **Design Phase:** The proposed code change would impact process load systems in new facilities or new processes added to existing facilities. Designers who issue specifications that refer to current code for pipe insulation thickness would not need to change their specifications. Designers who issue specifications that include a table of insulation thicknesses would need to update their specifications to reflect new insulation thickness requirements.

- **Permit Application Phase:** The proposed code change would impact the permit application phase for process loads. The Certificate of Compliance document, NRCC-PRC-E, would need to be provided to plans examiners during the permit application phase. The plans examiner would need to be aware of the code requirements and compliance document changes. The plans examiner would also need to understand how the code requirements should be integrated into the design, while ensuring that all existing codes and standards for subject facilities are being properly addressed. The plans examiner would review Certificate of Compliance documents and either provide guidance for not approved permit applications or provide approval to the design team.
- **Construction Phase:** The installation of thicker insulation on larger pipes may require some adjustments in the practices of insulation installers, but this would not be a major change. Plumbers may need to make modifications to ensure there is clearance around the piping to accommodate the insulation. However, this is not a common issue as most large diameter pipes are installed in a horizontal configuration with ample space. In existing facilities that were not designed to accommodate insulation as thick as is required by the proposed requirements, the piping layout may need to be modified to accommodate insulation. Reconfiguring piping can be a significant retrofit; the Statewide CASE Team is recommending that the mandatory pipe insulation requirements only be triggered for alterations if new pipe is being installed or if the existing pipes are being relocated.
- **Inspection Phase:** Building officials would have to familiarize themselves with the insulation thickness standards for process load piping. Most inspectors should be familiar with the minimum pipe insulation requirements because this proposal recommends using the same minimum pipe insulation requirements that already apply to nonresidential service water heating and space conditioning piping. Building inspectors would check insulation thicknesses from project documentation and visually confirm insulation was installed on pipes.

4. Market Analysis

4.1 Current 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 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, CEC 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 January 31, 2023.

The market for pipe insulation in industrial facilities is mature. California has a thriving industrial sector[5] and well-established GHG reduction goals, which has led to an increased demand for efficiency improvements in industrial facilities including insulation products and services. Growth in the California market for pipe insulation in industrial facilities is expected to continue as industrial operations continue as California seeks carbon neutrality by 2045.

There are several types of insulation materials including mineral fiber, polyurethane foam, polystyrene foam, and others. Each of these materials has their own unique properties and advantages, making them suitable for distinct types of industrial applications. The largest application being the insulation of pipes and tanks in industrial facilities. This is due to the substantial amount of heat generated by these operations and the need to maintain the temperature of the fluids being transported through the pipes.

The following companies have a strong presence in the market and offer a wide range of insulation products and services: Johns Manville, Cabot Corporation, Huntsman Corporation, Kingspan Group, Saint-Gobain, GAF, The Dow Chemical Company, Armacell, Thermaxx, and Johnson Controls.

California is the largest market for industrial pipe insulation in the western United States. Nevada, Arizona, and Oregon also have notable markets.

[5] More than 800 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). California's top manufacturing sectors include computer and electronic products; chemicals; food, beverage, and tobacco products; petroleum and coal products; and miscellaneous durable goods (National Association of Manufacturers n.d.)

4.2 Technical Feasibility and Market Availability

It is technically feasible to insulate all hot pipes above 120°F and chilled water and refrigeration lines. Pipe insulation technology is well accepted, and many industrial facilities already insulate pipes. Insulating hot or cold pipes is common with close to 100 percent of hot and cold piping being insulated in new construction and more than 90 percent of existing piping being insulated (Itron 2016). Potential market barriers for pipe and tank insulation in industrial facilities include:

1. Difficulty in retrofitting existing facilities: It can be difficult and costly to retrofit existing industrial facilities with insulation, especially if the facility was not designed with insulation in mind. The proposed code change accounts for this challenge by applying the mandatory pipe insulation requirements to alterations only if new pipes are installed or existing pipes are relocated. In both cases, the mandatory insulation requirements would be a design consideration for layout and clearance.
2. Lack of awareness and education: Some facilities may not be aware of the benefits of insulation or the available options and may not understand the return on investment that insulation can provide.
3. Installation costs: The cost of insulation materials and installation can be high, which can be a barrier for some industrial facilities.
4. Limited access to financing: Some industrial facilities may not have the necessary financial resources to invest in insulation.
5. Competition from other energy efficiency measures: Insulation may not be the only energy efficiency measure that an industrial facility is considering, and it may be competing with other options for limited resources.

The energy savings from pipe insulation are long-lasting but can be reduced by damage from factors like water exposure or physical wear and tear. To address these issues, using insulation materials and covers that are resistant to damage can be implemented, and proper installation can help prevent damage. In addition to energy savings, insulation can help to prevent condensation from forming on the exterior of the pipes, which can lead to corrosion and other issues.

4.3 Market Impacts and Economic Assessments

4.3.1 Impact on Builders

Builders of residential, commercial, and industrial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2025 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training to remain compliant with changes to design practices and building codes.

California's construction industry comprises approximately 93,000 business establishments and 943,000 employees (see Table 3). For 2022, total estimated payroll was about $78 billion. Nearly 72,000 of these business establishments and 473,000 employees are engaged in the residential building sector, while another 17,600 establishments and 369,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction roles (the industrial sector).

Table 3: California Construction Industry, Establishments, Employment, and Payroll in 2022 (Estimated)

Building Type	Construction Sectors	Establish ments	Employ ment	Annual Payroll (Billions $)
Residential	**All**	**71,889**	**472,974**	**31.2**
Residential	Building Construction Contractors	27,948	130,580	9.8
Residential	Foundation, Structure, & Building Exterior	7,891	83,575	5.0
Residential	Building Equipment Contractors	18,108	125,559	8.5
Residential	Building Finishing Contractors	17,942	133,260	8.0
Commercial	**All**	**17,621**	**368,810**	**35.0**
Commercial	Building Construction Contractors	4,919	83,028	9.0
Commercial	Foundation, Structure, & Building Exterior	2,194	59,110	5.0
Commercial	Building Equipment Contractors	6,039	139,442	13.5
Commercial	Building Finishing Contractors	4,469	87,230	7.4
Industrial, Utilities, Infrastructure, & Other (Industrial+)	**All**	**4,206**	**101,002**	**11.4**
Industrial+	Building Construction	288	3,995	0.4
Industrial+	Utility System Construction	1,761	50,126	5.5
Industrial+	Land Subdivision	907	6,550	1.0
Industrial+	Highway, Street, and Bridge Construction	799	28,726	3.1
Industrial+	Other Heavy Construction	451	11,605	1.4

Source: (State of California n.d.)

The proposed change to process load pipe insulation targets pipes in commercial or industrial buildings serving covered processes loads. The effects on the building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors.

4.3.2 Impact on Building Designers and Energy Consultants

Requiring that process piping have the same level of insulation required for service water heating and space conditioning has minimal impact on building designers and energy consultants. The primary change proposed by this measure is to bring industrial process pipe into the scope of existing nonresidential pipe insulation requirements. For those designers who design only industrial process facilities and not buildings, they would need to be aware of energy code requirements. The scope of the energy code has increasingly expanded to industrial facilities with requirements for refrigerated warehouses in 2008 to a major expansion in industrial process requirements in the 2013 Title 24, Part 6 with energy efficiency requirements for industrial process boilers, and compressed air systems.

Adjusting design practices to comply with changing building codes is within the normal practices of building designers. Building codes (including Title 24, Part 6) are typically updated on a three-year revision cycle, and building designers and energy consultants engage in continuing education and training 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 4 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for process load pipe insulation to affect firms that focus on industrial construction.

There is not a North American Industry Classification System (NAICS)[6] code specific to 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

[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.

establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 4 provides an upper bound indication of the size of this sector in California.

Table 4: California Building Designer and Energy Consultant Sectors in 2022 (Estimated)

Sector	Establishments	Employment	Annual Payroll (Millions $)
Architectural Services [a]	4,134	31,478	3,623.3
Building Inspection Services [b]	1,035	3,567	280.7

Source: (State of California n.d.)

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

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

4.3.3 Impact on Occupational Safety and Health

Pipe insulation plays a crucial role in occupational safety and health in industrial facilities. Insulating pipes that carry hot or cold fluids helps prevent burns, scalds, and other injuries to workers who come into contact with these pipes. It also helps to reduce the risk of fire, explosion, and leaks, which can lead to serious health hazards for workers. In addition, insulation can help control the indoor temperature in a facility, making the work environment more comfortable and reducing the risk of heat exhaustion and other heat-related illnesses. By improving the requirements for pipe insulation in Title 24, Part 6, workers are protected from these hazards and can work in a safe and healthy environment.

4.3.3.1 Estimating Impacts

Building owners and occupants would benefit from lower energy bills. The Statewide CASE Team does not expect the proposed code change for the 2025 code cycle to impact building owners or occupants adversely.

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

Pipe insulation can have a significant impact on component retailers, including manufacturers and distributors. Adequate insulation helps improve energy efficiency, leading to lower energy costs and improved sustainability. This, in turn, drives demand for insulated pipes and related products. As a result, component retailers can expect increased sales and revenue. In addition, improved insulation standards can lead to the development of new, more advanced insulation materials, providing additional growth opportunities for component retailers. It is important for component retailers to stay informed about the latest insulation requirements and industry developments to maximize their potential for growth and success.

4.3.5 Impact on Building Inspectors

Table 5 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 education and training to stay current on all aspects of building regulations, including energy efficiency. When industrial facilities are inspected for safety, inspection includes other requirements for steam and refrigerant piping, such the provision of maximum spacing of pipe hangers and observing whether piping is suitably insulated requires marginal additional inspection effort. Therefore, the Statewide CASE Team anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 5: Employment in California State and Government Agencies with Building Inspectors in 2022 (Estimated)

Sector	Govt.	Establishments	Employment	Annual Payroll (Million $)
Administration of Housing Programs [a]	State	18	265	29.0
	Local	38	3,060	248.6
Urban and Rural Development Admin [b]	State	38	764	71.3
	Local	52	2,481	211.5

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.

4.3.6 Impact on Statewide Employment

As described in Sections 4.3.1 through 4.3.5, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 4.4, the Statewide CASE Team estimated the proposed change in process load pipe insulation would affect statewide employment and economic output directly and indirectly through its impact on builders, designers, energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in process load pipe insulation would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

4.4 Economic Impacts

For the 2025 code cycle, the Statewide CASE Team used the IMPLAN model software,[8] along with economic information from published sources, and professional judgement to develop estimates of the economic impacts associated with each of the proposed code changes. Conceptually, IMPLAN estimates jobs created as a function of incoming cash flow in different sectors of the economy, due to implementing a code or a standard. The jobs created are typically categorized into direct, indirect, and induced employment. For example, cash flow into a manufacturing plant captures direct employment (jobs created in the manufacturing plant), indirect employment (jobs created in the sectors that provide raw materials to the manufacturing plant) and induced employment (jobs created in the larger economy due to purchasing habits of people newly employed in the manufacturing plant). Eventually, IMPLAN computes the total number of jobs created due to a code. The assumptions of IMPLAN include constant returns to scale, fixed input structure, industry homogeneity, no supply constraints, fixed technology, and constant byproduct coefficients. The model is also static in nature and is a simplification of how jobs are created in the macro-economy.

The economic impacts ld for this report are only estimates and are based on limited and to some extent speculative information. The IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that the 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 aspects of this economic analysis, the Statewide CASE Team relies on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the economic impacts presented below represent lower bound estimates of the actual benefits associated with this proposed code change.

Adoption of this code change proposal would result in modest economic impacts through the additional direct spending by industrial contractors, energy consultants, and building inspectors. The Statewide CASE Team does not anticipate that money saved

[8] IMPLAN employs economic data and advanced economic impact modeling to estimate economic impacts for interventions like changes to the California Title 24, Part 6 code. For more information on the IMPLAN modeling process, see www.IMPLAN.com.

by businesses or other organizations affected by the proposed 2025 code cycle regulations would result in additional spending by those businesses.

Table 6: Estimated Impact that Adoption of the Proposed Measure would have on the California Industrial Construction Sector

Type of Economic Impact	Employment (Jobs)	Labor Income (Million)	Total Value Added (Million)	Output (Million)
Direct Effects (Additional spending by Industrial Builders)	2	$180,553	$208,663	$355,396
Indirect Effect (Additional spending by firms supporting Industrial Builders)	1	$49,184	$77,179	$142,129
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	1	$65,968	$118,111	$187,988
Total Economic Impacts	**4**	**$295,706**	**$403,952**	**$685,514**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.[9]

4.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2025 code cycle regulation 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 4.4 would lead to modest changes in employment of existing jobs.

4.4.2 Creation or Elimination of Businesses in California

As stated in Section 4.4.1, 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 covered processes, 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.

[9] IMPLAN® model, 2020 Data, IMPLAN Group LLC, IMPLAN System (data and software), 16905 Northcross Dr., Suite 120, Huntersville, NC 28078 www.IMPLAN.com

4.4.3 Competitive Advantages or Disadvantages for Businesses in California

The proposed code changes would apply to all industrial facilities that are physically located in California, regardless of whether the business is headquartered inside or outside of the state.[10] Therefore, the Statewide CASE Team does not anticipate that the proposal 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.

4.4.4 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).[11] As

Table 7 shows that between 2017 and 2021, NPDI as a percentage of corporate profits ranged from a low of 18 in 2020 due to the worldwide economic slowdowns associated with the COVID-19 pandemic to a high of 35 percent in 2019, with an average of 26 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 7: 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 (Percent)
2017	518.473	1882.460	28
2018	636.846	1977.478	32
2019	690.865	1952.432	35
2020	343.620	1908.433	18
2021	506.331	2619.977	19
5-Year Average	***539.227***	***2068.156***	**26**

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

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in

[10] 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.

[11] 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.

investment, directly or indirectly, in any affected sectors of California's economy. Nevertheless, the Statewide CASE Team is able to derive a reasonable estimate of the change in investment by California businesses based on the estimated change in economic activity associated with the proposed measure and its expected effect on proprietor income, which the Statewide CASE Team used a conservative estimate of corporate profits, a portion of which the Statewide CASE Team assumes would be allocated to net business investment.[12]

4.4.5 Incentives for Innovation in Products, Materials, or Processes

The Statewide CASE Team does not expect the proposed code changes to have a measurable impact on innovation for insulation offerings.

4.4.6 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 California's General Fund, any state special funds, or local government funds.

4.4.6.1 Cost of Enforcement

Cost to the State: 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.

Cost to Local Governments: 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 2025 code change cycle. The building code is updated on a triennial basis, so local governments plan and budget for retraining for each code update. 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 3.6 and Appendix E, the Statewide CASE Team considered how the proposed code change

[12] 26 percent of proprietor income was assumed to be allocated to net business investment; see Table 7.

might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

Local governments have few facilities that might be covered by the process piping insulation requirement as the state has few process applications.

4.4.7 Impacts on Specific Persons

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 changes are not expected to result in impacts on specific persons. Refer to Section 2 for more details addressing energy equity and environmental justice.

4.5 Fiscal Impacts

4.5.1 Mandates on Local Agencies or School Districts

There are no relevant mandates to local agencies or school districts.

4.5.2 Costs to Local Agencies or School Districts

There are no costs to local agencies or school districts.

4.5.3 Costs or Savings to Any State Agency

There are no costs or savings to any state agencies.

4.5.4 Other Non-Discretionary Cost or Savings Imposed on Local Agencies

There are no added non-discretionary costs or savings to local agencies.

4.5.5 Costs or Savings in Federal Funding to the State

There are no costs or savings to federal funding to the state.

5. Energy Savings

5.1 Energy Savings Methodology

5.1.1 Key Assumptions for Energy Savings Analysis

The 3E Plus program was used to calculate the energy losses for bare pipes for various insulation thicknesses. 3E Plus runs for pipe diameters of 0.75 inches up to 10 inches were conducted for steam pipe temperatures corresponding to 15 psig, 50 psig, 100 psig and 150 psig. 3E Plus runs were also conducted for pipe diameters of 0.75 inches up to 10 inches for hot water pipes of 120°F, 140°F and 200°F, and cold-water pipes of -20°F, -10°F, 18°F and 40°F. The energy loss results in British thermal units per hour per foot (Btu/h/ft) from each 3E Plus run was entered into an excel sheet to calculate energy savings, utility cost savings, and installation costs. The following assumptions were made:

- The average summer temperature for the hottest climate zone in California, Climate Zone 13, was used for hot water and steam piping. This would provide the most conservative savings values. Pipes located in all other California climate zones would provide higher savings leading to better benefit-to-cost ratio. The ambient temperature of 85°F is also a conservative for piping located indoors as the average seasonal temperature for most indoor facilities would be lower than 85°F.
- For all chilled water pipes, the average winter temperature for the coldest climate zone in California, Climate Zone 1, was used. This provides the most conservative value for insulating chilled water pipes.
- Steel Pipe material: In industrial facilities, steel pipes, stainless steel pipes and copper pipes are all employed. The Statewide CASE Team used steel pipes for this evaluation. Based on the experience of the CASE Team and various online resources such as Pipes and Pipe Sizing for Steam Distribution, steel is the most common pipe material. Steel pipes provide the lowest cost to strength ratio. Stainless Steel and copper pipes come at a higher cost and are used only when required. Energy losses for bare steel pipes are greater than SST or copper, resulting in the highest energy savings of the three.
- For cold water pipes, the energy loss through the pipes was converted to kWh usage of the chiller. A coefficient of performance (COP) was assumed for each temperature; COP of 4.6 for 40°F, COP of 3.8 for 18°F, COP of 2.2 for -10°F, and COP of 1.8 for -20°F.
- The baseline for alterations is bare pipes for 10 percent of the overall pipes in the prototype. The analysis did not include an evaluation of upgrading insulation

on pipes that are currently insulated, but insulation is not as thick as would be required by the new minimum insulation requirements in Table 120.3-A.

- The baseline for new construction is industry standard practice with insulation ranging from 1.0 inch to 2.0 inches depending on process temperature. The estimated insulation thicknesses were obtained from the Itron report (Itron 2016).
- Average operating hours of 4,992 hours (two shifts, six days per week, six am to 10 pm) for a prototype industrial facility was also obtained from the same Itron Impact evaluation report.

Insulation thickness and R values for the baseline and new proposed code values are compared in Table 8 below.

Table 8: Baseline and Proposed Insulation Thickness and R-values by Fluid Operating Temperature Range

Nominal Pipe Diameter (inches)	Description	105–140°F	141–200°F	201–250°F	251–350°F	Above 350°F	Units
All	Rating Temperature	100	125	150	200	250	mean°F
	Conductivity	0.22-0.28	0.25-0.29	0.27-0.30	0.29-0.32	0.32-0.34	Btu-in/h-ft^2
< 1	Insulation thickness (proposed)	1	1.5	2.5	3	4.5	inches
	Insulation thickness thick (baseline)	0.5	1	1	1	1	inches
	R-value (proposed)	7.7	11.5	21	24	37	hr-°F-ft^2/Btu
	R-value (Baseline)	3.2	2.9	6.3	5.9	5.3	hr-°F-ft^2/Btu
1 to <1.5	Insulation thickness (proposed)	1.5	1.5	2.5	4	5	inches
	Insulation thickness thick (baseline)	1	1	1	1	1	inches
	R-value (proposed)	12.5	11	20	34	41	hr-°F-ft^2/Btu
	R-value (Baseline)	7.5	6.6	6.1	5.7	5.1	hr-°F-ft^2/Btu
1.5 to < 4	Insulation thickness (proposed)	1.5	2	2.5	4.5	5	inches
	Insulation thickness thick (baseline)	1	1	2	2	2	inches
	R-value (proposed)	11	14	17.5	35	37	hr-°F-ft^2/Btu
	R-value (Baseline)	6.7	2.6	9.2	8.5	7.7	hr-°F-ft^2/Btu
4 to < 8	Insulation thickness (proposed)	1.5	2	3	4.5	5	inches
	Insulation thickness thick (baseline)	1	2	2	2	2	inches
	R-value (proposed)	9	11	17	26	27	hr-°F-ft^2/Btu
	R-value (Baseline)	5.5	11.1	10.3	9.6	8.7	hr-°F-ft^2/Btu
8 and larger	Insulation thickness (proposed)	1.5	2	3	4.5	5	inches
	Insulation thickness thick (baseline)	1	2	2	2	2	inches
	R-value (proposed)	8	10	14.5	22	23	hr-°F-ft^2/Btu
	R-value (Baseline)	5	10	6	6	5	hr-°F-ft^2/Btu

5.1.2 Energy Savings Methodology per Prototypical Building

The Statewide CASE Team measured per-unit energy savings expected from the proposed code changes in several ways to quantify key impacts. First, savings were calculated by fuel type. Electricity savings were measured in terms of both energy usage and peak demand reduction. Natural gas savings were quantified in terms of energy usage. Second, the Statewide CASE Team calculated Source Energy Savings. Source Energy represents the total amount of raw fuel required to operate a building. In addition to all energy used from on-site production, source energy incorporates all transmission, delivery, and production losses. The hourly Source Energy values provided by CEC are proportional to GHG emissions. Finally, the Statewide CASE Team calculated Long-term Systemwide Cost (LSC) Savings, formerly known as Time Dependent Valuation (TDV) Energy Cost Savings. LSC Savings are calculated using hourly LSC factors for both electricity and natural gas provided by the CEC. These LSC hourly factors are projected over the 30-year life of the building and incorporate the hourly cost of marginal generation, transmission and distribution, fuel, capacity, losses, and cap-and-trade-based CO_2 emissions.

The CEC directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings (California Energy Commission 2023). The prototype building that the Statewide CASE Team used in the analysis is presented in Table 9.

A prototype for industrial facilities was created to estimate the per-unit impacts for the proposed code language. A single calculation model was used to estimate energy savings for existing systems, new construction as well as additions and alterations.

For statewide savings estimates, the Statewide CASE Team assumed that without an explicit requirement for pipe insulation, 10 percent of installed piping was not being insulated in newly constructed factories or in factory expansions. Similarly for alterations, the Statewide CASE Team expects that 10 percent of piping insulation in existing facilities is damaged and needs to be replaced.

Table 9: Prototype Building Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (Square Feet)	Description
Industrial Pipe Insulation	1	175,000	Average industrial facility estimated at approximately 175,000 ft^2.

The Statewide CASE Team estimated LSC, source energy, electricity, natural gas, peak demand, and GHG impacts by simulating the proposed code change in an Excel spreadsheet using results from 3E Plus.

The model estimated a typical prototype building to be 175,000 square feet. The length of pipes of various diameters were estimated per building as shown in Table 10 below. Industrial facilities can vary greatly in the amount of steam, hot water, and chilled water piping they have. Facilities such as food processing commonly have all three. Dairy processing for example, will have steam for pasteurization, hot water for clean in place (CIP) units, and chilled water for process cooling. Other industrial facilities may only have one or two of these three. A prototype building containing all three was used for the statewide savings to simplify the model. Conservative values for the total amount of piping and percentage of piping not insulated was used to compensate for any over estimation. Ambient temperatures that would yield the most conservative energy savings were also used in the analysis.

Table 10: Pipe Lengths and Diameters for Covered Processes Per Prototype Building

Hot Water **Pipe Diameter (inches)**	*Hot Water* **Pipe Length (feet)**	*Steam* **Pipe Diameter (inches)**	*Steam* **Pipe Length (feet)**	*Chilled Water and Brine* **Pipe Diameter (inches)**	*Chilled Water and Brine* **Pipe Length (feet)**
0.75	500	0.75	500	0.75	500
1	1000	1	1000	1	1000
3	500	3	1000	3	200
6	200	6	500	6	200
10	100	10	300	10	200
-	Total: 2,300	-	Total: 3,300	-	Total: 2,100

Various steam, hot-water, and-cold water temperatures were modeled in the 3E Plus. The percentage of facilities across California that operate using these temperatures were estimated using the values shown in Table 11.

Table 11: Operating Temperatures per Percentage of Facilities

Hot Water **Temperature (°F)**	*Hot Water* **Percent of Facility**	*Steam* **Temperature (°F)**	*Steam* **Percent of Facility**	*Chilled Water and Brine* **Temperature (°F)**	*Chilled Water and Brine* **Percent of Facility**
120	30%	250	20%	40	20%
140	30%	298	30%	18	30%
200	40%	338	40%	-10	30%
-	-	366	10%	-20	20%

As a reminder, Section 120.3 of 2022 Title 24, Part 6 includes mandatory requirements for pipe insulation, but the requirements do not apply to pipes used for covered processes. Table 120.3-A, which is derived from ASHRAE 90.1, lists specific requirements for minimum insulation thicknesses and R-values for different pipe diameters and process fluid temperatures.

Detailed calculations using 3E Plus, a U.S. DOE approved tool to calculate heat loss, were performed to evaluate the optimum insulation for steam, hot water, and cold-water pipes. Energy loss and energy savings calculations were completed for steam pipes, hot water pipes, and chilled water pipes above ½ inch diameter using fiberglass insulation.

The Statewide CASE Team calculated the energy savings associated with insulating bare pipe to the insulation levels in Table 120.3 of the Title 24, Part 6 (energy code) per 100 linear feet of pipe. The base case assumed 10 percent bare pipe and 90 percent of pipes insulated at a lower value than proposed by Table 120.3-A. The standard practice insulation thickness was estimated from the insulation thickness values identified in the Itron impact evaluation report (Itron 2016). The proposed case was insulated pipe meeting Table 120.3-A requirements. The tables in Section 5.2 show the annual energy savings, the lifecycle cost savings, the installed cost, and the benefit-to-cost ratio of adding these levels of insulation to bare pipes.

For statewide savings estimates, the Statewide CASE Team is assuming that without an explicit requirement for pipe insulation that 10 percent of installed piping is not being insulated in newly constructed factories or in factory expansions (90 percent is being installed with insulation). Similarly for alterations the Statewide CASE Team expects that 10 percent per year of piping is being added in existing factories and without the explicit requirements for pipe insulation that 10 percent of the projects would not be insulated (i.e., 10 percent of new piping per year with 10 percent of that newly installed piping not being insulated). From the existing estimated 753,431 square feet of existing facilities, 10 percent or 75,343 square feet would be impacted. Ten percent of the piping in the impacted facilities is estimated to be impacted by this code.

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 12 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Specifically for alterations, the base case (Standard Design) conditions assume 10 percent of existing pipes are un-insulated due to damage, removal for equipment service, alterations, or additions.

Table 12: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Objects Modified	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
Industrial Pipe Insulation	All	Pipe Insulation Levels	Manufacturing New Construction	90% Standard Practice Insulation, 10% Bare Pipe	Insulated Pipes to table 120.3
			Manufacturing Alterations	10% Bare Pipe	Insulated Pipes to table 120.3

Per-unit energy impacts in Section 5.2 present savings per prototypical building. Annual energy, GHG, and peak demand impacts for each prototype building were translated into impacts per square foot by dividing by the floor area of the prototype building. This step allows for an easier comparison of savings across different building types and enables a calculation of statewide savings using the construction forecast that is published in terms of floor area by building type.

5.1.3 Statewide Energy Savings Methodology

The per-unit energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the CEC provided. The Statewide Construction Forecasts estimate new construction/additions that would occur in 2026, the first year that the 2025 Title 24, Part 6 requirements are in effect (California Energy Commission 2023). They also estimate the amount of total existing building stock in 2026, which the Statewide CASE Team used to approximate savings from building alterations. The construction forecast provides construction (new construction/additions and existing building stock) by building type and climate zone, as shown in Appendix A. This proposal estimates that approximately two million square feet of new industrial space is constructed per year and that 75 million square feet per year of industrial space undergo alterations that would trigger this measure.

For statewide savings estimates, the Statewide CASE Team is assuming that without an explicit requirement for pipe insulation that 10 percent of installed piping is not being insulated in newly constructed factories or in factory expansions (90 percent is being installed with standard practice insulation). Similarly for alterations the Statewide CASE Team expects that 10 percent per year of piping is being added in existing factories and without the explicit requirements for pipe insulation that 10 percent of the projects would not be insulated.

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

5.2 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per prototypical building t are presented in Table 13. The figures do account for naturally occurring market. In other words, this assumes that 10 percent of all piping is not insulated in the base case. Savings per prototype building for the first year are expected to be 6,172 kWh/year and 1,259,600 kBtu/year. Demand reduction is expected to be 0.016 kW for existing facilities.

First year savings per prototype building for new construction is expected to be 6,172 kWh/year, and 824,000 kBtu/year. Demand reduction is expected to be 0.016 kW.

Table 13: First year energy savings per 175,000 square foot prototype building

Application	Electricity Savings (kWh/year/year)	Peak Demand Reduction (kW/year)	Natural Gas Savings (Therms/year)	Source Energy Savings (Therms/year)
New Construction or Addition Prototype	6,172	0.016	8,240	7,519
Alteration Prototype	6,172	0.016	12,596	11,426

6. Cost and Cost-Effectiveness

6.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the Long-term Systemwide Cost (LSC) hourly factors to the energy savings estimates that were derived using the methodology described in Section 5.1. LSC hourly factors are a normalized metric to calculate energy cost savings that account 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. In this case, the period of analysis used is 30 years.

The CEC requested energy cost savings over the 30-year period of analysis in both 2026 present value dollars (2026 PV$) and nominal dollars. The cost-effectiveness analysis uses energy cost values in 2026 PV$. Costs and cost-effectiveness using and 2026 PV$ are presented in Section 6 of this report. CEC uses results in nominal dollars to complete the Economic and Fiscal Impacts Statement (From 399) for the entire package of proposed change to Title 24, Part 6. Appendix G presents energy cost savings results in nominal dollars.

This measure applies to additions and alterations to existing facilities as well as new construction.

6.2 Energy Cost Savings Results

Energy savings, LSC, installation cost, maintenance costs, and benefit-to-cost ratios per one hundred feet of pipe are presented in Table 14 and Table 15 and show that pipe insulation is very cost-effective for all temperatures and pipe diameters except for the 40°F to 60°F range. Footnote 1 to Table 120.3-A in Title 24, Part 6 (for space cooling systems - chilled water, refrigerant and brine), indicates that “These thickness are based on energy efficiency considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.” It may be more accurate to recognize that the rationale for any insulation for the 40°F to 60°F range, besides saving energy is to prevent moisture damage and preventing slip and fall safety hazards.

Table 14: Energy Savings, Energy Cost Savings, Maintenance Cost Savings, and Benefit-to-Cost Ratio from Insulating 100 linear feet of Hot Water and Steam Pipes by Fluid Operating Temperature Range

Nominal Pipe Diameter (inches)	Description	105-140°F	141-200°F	201-250°F	251-350°F	Above 350°F	Units
All	Conductivity	0.22-0.28	0.25-0.29	0.27-0.30	0.29-0.32	0.32-0.34	Btu-in/h-ft^2
< 1	Insulation thickness	1	1.5	2.5	3	4.5	inches
	R-value	R 7.7	R 11.5	R 21	R 24	R 37	hr-°F-ft^2/Btu
	Natural Gas Savings	331	1,307	2,557	3,735	5,931	Btu/hr-100 lin ft
	Natural Gas Savings	17	65	128	186	296	Therm/year-100 lin ft
	LSC Savings	$883.8	$3,486.5	$6,824.5	$9,965.8	$15,827.2	LCS$/100 lin ft
	Incremental Installation Cost	$296	$676	$886	$1,354	$2,628	$/100 lin ft
	Incremental Maintenance Cost	$51	$116	$152	$232	$449	$/100 lin ft
	Benefit-to-cost ratio	2.55	4.40	6.57	6.28	5.14	N/A
1 to <1.5	Insulation thickness	1.5	1.5	2.5	4	5	inches
	R-value	R 12.5	R 11	R 20	R 34	R 41	hr-°F-ft^2/Btu
	Natural Gas Savings	327	1,478	2,789	4,384	6,719	Btu/hr-100 lin ft
	Natural Gas Savings	16	74	139	219	335	Therm/year-100 lin ft
	LSC Savings	$872.8	$3,943.8	$7,443.6	$11,698.9	$17,928.6	LCS$/100 lin ft
	Incremental Installation Cost	$401	$401	$1,198	$2,361	$3,790	$/100 lin ft
	Incremental Maintenance Cost	$69	$69	$205	$404	$648	$/100 lin ft
	Benefit-to-cost ratio	1.86	8.39	5.31	4.23	4.04	N/A
1.5 to < 4	Insulation thickness	1.5	2	2.5	4.5	5	inches
	R-value	R11	R 14	R 17.5	R 35	R 37	hr-°F-ft^2/Btu
	Natural Gas Savings	850	3,416	5,709	9,420	14,225	Btu/hr-100 lin ft
	Natural Gas Savings	42	171	285	470	710	Therm/year-100 lin ft
	LSC Savings	$2,267.9	$9,115.0	$15,234.1	$25,136.7	$37,959.5	LCS$/100 lin ft
	Incremental Installation Cost	$560	$1,126	$1,459	$4,143	$5,274	$/100 lin ft
	Incremental Maintenance Cost	$96	$192	$249	$708	$902	$/100 lin ft
	Benefit-to-cost ratio	3.46	6.92	8.92	5.18	6.15	N/A

Nominal Pipe Diameter (inches)	Description	105-140°F	141-200°F	201-250°F	251-350°F	Above 350°F	Units
4 to < 8	Insulation thickness	1.5	2	3	4.5	5	inches
	R-value	R 9	R 11	R 17	R 26	R 27	hr-°F-ft^2/Btu
	Natural Gas Savings	1,583	6,479	9,882	15,607	23,572	Btu/hr-100 lin ft
	Natural Gas Savings	79	323	493	779	1,177	Therm/year-100 lin ft
	LSC Savings	$4,224.0	$17,288.9	$26,370.3	$41,647.0	$62,899.3	LCS$/100 lin ft
	Incremental Installation Cost	$771	$482	$2,426	$5,285	$6,940	$/100 lin ft
	Incremental Maintenance Cost	$132	$82	$415	$904	$1,186	$/100 lin ft
	Benefit-to-cost ratio	4.68	30.65	9.28	6.73	7.74	N/A
8 and larger	Insulation thickness	1.5	2	3	4.5	5	inches
	R-value	R 8	R 10	R 14.5	R 22	R 23	hr-°F-ft^2/Btu
	Natural Gas Savings	2,666	10,025	15,696	24,585	37,165	Btu/hr-100 lin ft
	Natural Gas Savings	133	500	784	1,227	1,855	Therm/year-100 lin ft
	LSC Savings	$7,114.3	$26,751.8	$41,884.8	$65,604.2	$99,171.5	LCS$/100 lin ft
	Incremental Installation Cost	$1,073	$691	$3,399	$7,381	$9,711	$/100 lin ft
	Incremental Maintenance Cost	$183	$118	$581	$1,262	$1,660	$/100 lin ft
	Benefit-to-cost ratio	5.66	33.04	10.52	7.59	8.72	N/A

Table 15: Energy Savings, Energy Cost Savings, Maintenance Cost Savings, and Benefit-to-Cost Ratio from Insulating Chilled Water, Refrigerant and Brine Pipes

Nominal Pipe Diameter (in.)	Description	Fluid Temp: 40-60°F	Fluid Temp: Below 40°F	Units
All	Conductivity	0.21-0.27	0.20-0.26	Btu-in/h-ft^2
< 1	Insulation Thickness	0.5	1	Inches
	R-value	R 3	R 8.5	hr-°F-ft^2/Btu
	Natural Gas Savings	176	2,262	Btu/hr-100 lin ft
	Electricity Savings	56	1,477	kWh/year-100 lin ft
	LSC Savings	$339.7	$9,013.3	LCS$/100 lin ft
	Incremental First Cost	$1,813	$1,927	$/100 lin ft
	Incremental Maintenance Cost	$310	$329	$/100 lin ft
	Benefit-to-cost ratio	0.16	3.99	
1 to <1.5	Ins thick	0.5	1.5	Inches
	R value	R 3	R 14	hr-°F-ft^2/Btu
	Savings	218	2,954	Btu/hr-100 lin ft
	Savings	69	1,929	kWh/year-100 lin ft
	LSC	$420.7	$11,770.7	LCS$/100 lin ft
	Inc Cost	$1,583	$1,935	$/100 lin ft
	Maintenance	$271	$331	$/100 lin ft
	Benefit-to-cost ratio	0.23	5.19	LC Benefit/LC Cost
1.5 to < 4	Ins thick	1	1.5	Inches
	R value	R 7	R 12	hr-°F-ft^2/Btu
	Savings	636	7,351	Btu/hr-100 lin ft
	Savings	201	4,801	kWh/year-100 lin ft
	LSC	$1,227.4	$29,291.3	LCS$/100 lin ft
	Inc Cost	$2,386	$2,707	$/100 lin ft
	Maintenance	$408	$463	$/100 lin ft
	Benefit-to-cost ratio	0.44	9.24	
4 to < 8	Ins thick	1	1.5	Inches
	R value	R 6	R 10	hr-°F-ft^2/Btu
	Savings	1,161	13,395	Btu/hr-100 lin ft
	Savings	367	8,748	kWh/year-100 lin ft
	LSC	$2,240.6	$53,374.6	LCS$/100 lin ft
	Inc Cost	$3,532	$3,950	$/100 lin ft
	Maintenance	$604	$675	$/100 lin ft
	Benefit-to-cost ratio	0.54	11.54	
8 and larger	Ins thick	1	1.5	Inches
	R value	R 5	R 9	hr-°F-ft^2/Btu
	Savings	1,513	17,308	Btu/hr-100 lin ft
	Savings	479	11,303	kWh/year-100 lin ft
	LSC	$2,920.0	$68,966.6	LCS$/100 lin ft
	Inc Cost	$4,411	$4,841	$/100 lin ft
	Maintenance	$754	$828	$/100 lin ft
	Benefit-to-cost ratio	0.57	12.17	

Table 16 presents the energy cost savings per 1,000 square feet of industrial space for newly constructed buildings, additions, and alterations that are realized over a 30-year period. The LSC hourly factors methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 16: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis — Per 1,000 Square Foot of Industrial space — New Construction and Alterations – Prototype

	30-Year LSC Electric Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
New Construction	$215.18	$2,516.93	$2,732.11
Alterations	$215.18	$3,847.32	$4,062.50

6.3 Incremental First Cost

The incremental first cost of insulation was determined by getting pricing and a couple of sample proposals from insulation contractors. The cost was supplied for 1-inch of insulation and a formula was provided by the contractor to estimate cost above 1-inch of insulation.

Sacramento area costs were pulled from RS Means; the higher costs found in Sacramento relative other areas in California's central valley allow analysis to be more conservative, while the high number of industrial facilities in Sacramento provides a more accurate assessment. Higher cost areas such as San Francisco have few industrial facilities and therefore not good representative city. The average contractor costs and costs obtained from RS Means were used to conduct the financial evaluation. The Statewide CASE Team included total costs including overhead and profit (O&P).

Mineral fiber insulation with all service jackets was used for both calculations and cost estimates as it is the most common type of insulation.

Table 17: Installed Insulation Cost per 100 linear feet

Pipe Diameter (inches)	Price	1" insulation	1.5" insulation	2" insulation	2.5" insulation	3" insulation	4.5" insulation	5" insulation
0.75"	High	$2,289	$2,518	$3,021	$3,626	$4,351	$6,265	$7,518
	Low	$1,565	$2,097	$1,330	$1,616	$1,827	$2,460	$2,671
	Avg	$1,927	$2,307	$2,176	$2,621	$3,089	$4,363	$5,095
1"	High	$2,429	$2,672	$3,206	$3,848	$4,617	$6,649	$7,978
	Low	$980	$1,199	$1,402	$1,616	$1,827	$2,460	$2,671
	Avg	$1,705	$1,935	$2,304	$2,732	$3,222	$4,554	$5,324
1.5"	High	$2,708	$2,979	$3,575	$4,289	$5,147	$7,412	$8,895
	Low	$990	$1,247	$1,522	$1,785	$2,051	$2,849	$3,115
	Avg	$1,849	$2,113	$2,548	$3,037	$3,599	$5,131	$6,005
2"	High	$2,988	$3,287	$3,944	$4,733	$5,680	$8,179	$9,814
	Low	$1,109	$1,322	$1,601	$1,836	$2,082	$2,820	$3,066
	Avg	$2,049	$2,304	$2,773	$3,284	$3,881	$5,499	$6,440
2.5"	High	$3,267	$3,594	$4,312	$5,175	$6,210	$8,942	$10,731
	Low	$1,159	$1,411	$1,752	$2,034	$2,330	$3,220	$3,516
	Avg	$2,213	$2,502	$3,032	$3,604	$4,270	$6,081	$7,123
4"	High	$4,105	$4,516	$5,419	$6,502	$7,803	$11,236	$13,483
	Low	$1,483	$1,800	$2,238	$2,595	$2,973	$4,105	$4,483
	Avg	$2,794	$3,158	$3,828	$4,549	$5,388	$7,671	$8,983
6"	High	$5,223	$5,745	$6,894	$8,273	$9,928	$14,296	$17,155
	Low	$1,840	$2,154	$2,740	$3,145	$3,595	$4,945	$5,395
	Avg	$3,532	$3,950	$4,817	$5,709	$6,761	$9,620	$11,275
10"	High	$7,459	$8,205	$9,846	$11,815	$14,178	$20,416	$24,500
	Low	$2,832	$3,203	$3,983	$4,490	$5,066	$6,792	$7,368
	Avg	$5,146	$5,704	$6,914	$8,153	$9,622	$13,604	$15,934

6.4 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 30-year period of analysis. The present value of equipment maintenance costs (or savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2025 LSC hourly factors. The present value of maintenance costs that occurs in the n^th year is calculated as follows:

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

The estimated amount of missing or damaged insulation that would need to be replaced over a 30-year period is approximately 30 percent. Using a current cost of $304 per 1,000 square feet and a discount rate of three percent, the estimated 30-year maintenance cost is $52 per 1,000 square feet. Estimating approximately 175,000 square feet per facility, the maintenance cost per facility is $9,100.

6.5 Cost-effectiveness

This measure proposes a mandatory requirement. As such, a cost analysis is required to demonstrate that the measure is cost-effective over the 30-year period of analysis.

The CEC establishes the procedures for calculating cost-effectiveness. The Statewide CASE Team collaborated with CEC 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 30-year period of analysis were included. The LSC cost savings from electricity and 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 CEC's definitions, a measure is cost-effective if the benefit-to-cost ratio is greater than 1.0. The benefit-to-cost ratio is calculated by dividing the cost benefits realized over 30 years by the total incremental costs, which includes maintenance costs for 30 years. The benefit-to-cost ratio was calculated using 2026 PV costs and cost savings. Results of the per-unit cost-effectiveness analyses are presented in Table 18 for new construction/additions and alterations. The proposed measure saves money over the 30-year period of analysis relative to the existing conditions. The proposed code change is cost-effective in every climate zone.

Table 18: 30-Year Cost-Effectiveness Summary Per 1,000 Square Foot — New Construction/Additions and Alterations

Building Prototype	Benefits LSC Energy Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
Industrial Pipe Insulation — New Construction and Additions	$2,732	$304.30	8.98
Industrial Pipe Insulation — Alterations	$4,063	$208.41	19.49

a. **Benefits: LSC Energy Savings + Other PV Savings:** Benefits include lifecycle energy cost savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal — inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. PV maintenance cost savings are included if PV of proposed maintenance costs is less than PV of current maintenance costs. Residual value of equipment is included if residual value of proposed system is greater than residual value of current system at the end of the CASE analysis period.

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.

7. First-Year Statewide Impacts

7.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction ,additions, and alterations by multiplying the per-unit savings, which are presented in Section 5.2, by assumptions about the percentage of newly constructed and existing buildings that would be impacted by the proposed code. The statewide new construction and existing buildings forecast for 2026 is presented in Appendix A, as are the Statewide CASE Team's assumptions about the percentage of new construction that would be impacted by the proposal (by climate zone and building type).

The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2026. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 19 presents the first-year statewide energy and energy cost savings from newly constructed buildings and additions and from alterations by climate zone. The energy savings calculated per 1,000 square feet was multiplied by the total affected new construction space and affected alterations of existing space. The affected new construction space was assumed to be 100 percent of the new construction estimated of 900,000 square feet, with 90 percent of that going from industry standard baseline to code and 10 percent going from bare pipe to code. The affected existing space was assumed to be 10 percent or 57,343,000 square feet due to alterations.

While a statewide analysis is crucial to understanding broader effects of code change proposals, there is potential to disproportionately impact DIPs that needs to be considered. Refer to Section 2 for more details addressing energy equity and environmental justice.

Table 19: Statewide Energy and Energy Cost Impacts — New Construction, Additions, and Alterations

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Million Square Feet)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued Energy Cost Savings (Million 2026 PV$)
All — New Construction and Additions	0.9	0.032	0.00004	0.04	3.88	2.45
All - Alterations	75.34	2.657	0.00314	5.42	491.9	304.76
Total	**76.24**	**2.689**	**0.0032**	**5.46**	**495.82**	**307.2**

a. First-year savings from all buildings completed statewide in 2026.

7.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions associated with energy consumption using the hourly GHG emissions factors that CEC developed along with the 2025 LSC hourly factors and an assumed cost of $123.15 per metric tons of carbon dioxide equivalent emissions (metric tons CO2e).

The 2025 LSC hourly 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).[13] The cost-effectiveness analysis presented in Section 6 of this report does not include the cost savings from avoided GHG emissions. 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 LSC hourly factors.

[13] The permit cost of carbon is equivalent to the market value of a unit of GHG emissions in the California Cap-and-Trade program, while social cost of carbon is an estimate of the total economic value of damage done per unit of GHG emissions. Social costs tend to be greater than permit costs. See more on the Cap-and-Trade Program on the California Air Resources Board website: https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program.

Table 20 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 365,923 (metric tons CO2e) would be avoided.

Table 20: First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings [a] (GWh/year)	Reduced GHG Emissions from Electricity Savings [a] (Metric Tons CO2e)	Natural Gas Savings [a] (Million Therms/year)	Reduced GHG Emissions from Natural Gas Savings [a] (Metric Tons CO2e)	Total Reduced GHG Emissions[b] (Metric Ton CO2e)	Total Monetary Value of Reduced GHG Emissions[c] ($)
New Construction & Additions	0.032	2.5	0.04	232.4	234.9	$28,924
Alterations	2.657	207.2	5.42	29,565.8	29,773	$3,666,467
Total	**2.689**	**209.7**	**5.46**	**29,798**	**30,008**	**$3,695,391**

a. First-year savings from all buildings completed statewide in 2026.

b. GHG emissions savings were calculated using hourly GHG emissions factors published alongside the LSC hourly factors and Source Energy hourly factors by CEC here: https://www.energy.ca.gov/files/2025-energy-code-hourly-factors

c. The monetary value of avoided GHG emissions is based on a proxy for permit costs (not social costs) derived from the 2022 TDV Update Model published by CEC here: https://www.energy.ca.gov/files/tdv-2022-update-model

7.3 Statewide Water Use Impacts

The proposed code change would not result in water savings.

7.4 Statewide Material Impacts

The proposed code change would increase the production and use of insulation. Insulation volume was calculated based on insulation thickness, estimated pipe runs of various sizes per facility as shown in Table 10 and an estimated insulation density of 5.0 pounds per cubic feet. The (Fiberglass Pipe Insulation Product Data Sheet) by Owens Corning lists the density of fiberglass between 3.5 to 5.5 pounds per cubic feet. A density of 5.0 per square foot was chosen as a slightly conservative value.

Table 21 presents the per unit and statewide impacts. See Appendix D for more details.

Table 21: First-Year Statewide Impacts on Material Use

Material	Impact	Per-Unit Impacts (Pounds per 1000 Square Foot)	First-Year [a] Statewide Impacts (Pounds)
Mercury	No Change	-	-
Lead	No Change	-	-
Copper	No Change	-	-
Steel	No Change	-	-
Plastic	No Change	-	-
Insulation	**Increase**	**50**	**3,812,344**

a. First-year savings from all buildings completed statewide in 2026.

7.5 Other Non-Energy Impacts

As mentioned in Section 4.3.3, pipe insulation plays a crucial role in occupational safety and health in industrial facilities. Insulating pipes that carry hot or cold fluids helps prevent burns, scalds, and other injuries to workers who come into contact with pipes. Workers would have improved protection from these hazards if CEC adopts this proposed code change.

8. Proposed Revisions to Code Language

8.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2022 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

8.2 Standards

This proposal would modify the following section of Title 24, Part 6.

SECTION 100.0 — SCOPE

…

F. **Covered processes.**

a. Sections applicable. Sections 110.2, 120.3, 120.6 and 140.9 apply to covered processes.

b. Compliance approaches. In order to comply with Part 6, covered processes must meet the requirements of:

   a. The applicable mandatory measures in Sections 110.2, 120.3 and 120.6; and

   b. Either:

      i. The performance approach requirements of Section 140.1; or

      ii. The prescriptive approach requirements of Section 140.9.

Note: If covered processes do not have prescriptive requirements, then only the applicable mandatory measures in Sections 110.2, 120.3 and 120.6 must be met.

TABLE 100.0-A APPLICATION OF STANDARDS

Occupancies	Application	Mandatory	Prescriptive	Performance	Alterations
…					
Covered Processses[1]	Envelope, Ventilation, Process Loads	110.2, 120.3, 120.6	140.9	140.1	110.2, 120.3, 120.6, 140.9, 141.1

SECTION 100.1 — DEFINITIONS AND RULES OF CONSTRUCTION

…

PROCESS, COVERED is a process that is regulated under Part 6, Sections 120.3, 120.6 and 140.9, which includes computer rooms, data centers, elevators, escalators and moving walkways, laboratories, enclosed parking garages, commercial kitchens, refrigerated warehouses, commercial refrigeration, compressed air systems, process boilers, process heating and cooling piping, and controlled environment horticultural spaces.

SECTION 120.3 — REQUIREMENTS FOR PIPE INSULATION

Nonresidential and hotel/motel buildings shall comply with the applicable requirements of Sections 120.3(a) through 120.3(c).

(a) **General requirements.** The piping conditions listed below for space-conditioning, ~~and~~ service water-heating, and process heating and process cooling piping systems with fluid normal operating temperatures listed in Table 120.3-A, the fluid distribution system shall have at least the amount of insulation specified in Subsection (c):

1. **Space cooling system~~s~~ piping.** All refrigerant suction, chilled water, and brine fluid distribution systems.
2. **Space heating system~~s~~ piping.** All refrigerant, steam, steam condensate and hot water fluid distribution systems.
3. **Service water-heating system~~s~~ piping.**
   A. Recirculating system piping, including the supply and return piping to the water heater.
   B. The first 8 feet of hot and cold outlet piping, including piping between a storage tank and a heat trap, for a nonrecirculating storage system.
   C. Pipes that are externally heated.
4. **Process heating system piping.** All refrigerant, steam, steam condensate and hot water fluid distribution systems for heating a process unrelated to space conditioning or service water-heating.
5. **Process cooling system piping.** All refrigerant suction, chilled water, and brine fluid distribution systems for cooling a process unrelated to space conditioning.

Insulation conductivity shall be determined in accordance with ASTM C335 at the mean temperature listed in Table 120.3-A, and shall be rounded to the nearest 1/100 Btu-inch per hour per square foot per°F. Fluid distribution systems include all elements that are in series with the fluid flow, such as pipes, fittings, pumps, valves, strainers, coil u-bends, and air separators, but not including elements that are not in series with the fluid flow, such as expansion tanks, fill lines, chemical feeders, and drains.

Exception to Section 120.3(a)2: Heat pump refrigerant vapor line shall be installed with a minimum of 0.5 inch thick or R-3.0 insulation for nonresidential buildings and 0.75 inch thick or R-6.0 insulation for residential buildings. No insulation is required on the refrigerant liquid line.

(b) **Insulation protection.** Pipe insulation shall be protected from damage due to sunlight, moisture, equipment maintenance and wind. Protection shall, at minimum, include the following:

1. Pipe insulation exposed to weather shall be protected by a cover suitable for outdoor service. The cover shall be water retardant and provides shielding from solar radiation that can cause degradation of the material. Adhesive tape shall not be used to provide this protection.
2. Pipe insulation covering chilled water piping and refrigerant suction piping located outside the conditioned space shall include, or be protected by, a Class I or Class II vapor retarder. All penetrations and joints shall be sealed.

3. Pipe insulation buried below grade must be installed in a water proof and noncrushable casing or sleeve.

(c) **Insulation thickness**

1. For insulation with a conductivity in the range shown in Table 120.3-A for the applicable fluid temperature range, the insulation shall have the applicable minimum thickness or R-value shown in Table 120.3-A.
2. For insulation with a conductivity outside the range shown in Table 120.3-A for the applicable fluid temperature range, the insulation shall have a minimum R-value shown in Table 120.3-A or thickness as calculated:

MINIMUM INSULATION THICKNESS EQUATION

$$T = PR\left[\left(1 + \frac{t}{PR}\right)^{\frac{K}{k}} - 1\right]$$

WHERE:

T = insulation thickness for material with conductivity K, inches.

PR = actual outside radius, inches.

t = Insulation thickness from Table 120.3-A, inches.

K = Conductivity of alternate material at the mean rating temperature indicated in Table 120.3-A for the applicable fluid temperature range, in Btu-inch per hour per square foot per°F.

k = The lower value of the conductivity range listed in Table 120.3-A for the applicable fluid temperature range, Btu-inch per hour per square foot per°F.

Table 120.3-A PIPE INSULATION THICKNESS

Fluid Operating Temperature Range (°F)	Insulation Conductivity: Conductivity (in Btu·in/h·ft^2·°F)	Insulation Conductivity: Mean Rating Temperature (°F)		Nominal Pipe Diameter (in inches): < 1	1 to <1.5	1.5 to < 4	4 to < 8	8 and larger
Space heating, ~~and~~ Service Water Heating Systems (Steam, Steam Condensate, Refrigerant, Space Heating, Service Hot Water), and Process Heating Systems				**Minimum Pipe Insulation Required (Thickness in inches or R-value)**				
Above 350	0.32-0.34	250	Inches	4.5	5.0	5.0	5.0	5.0
			R-value	R 37	R 41	R 37	R 27	R 23
251-350	0.29-0.32	200	Inches	3.0	4.0	4.5	4.5	4.5
			R-value	R 24	R 34	R 35	R 26	R 22
201-250	0.27-0.30	150	Inches	2.5	2.5	2.5	3.0	3.0
			R-value	R 21	R 20	R 17.5	R 17	R 14.5
141-200	0.25-0.29	125	Inches	1.5	1.5	2.0	2.0	2.0
			R-value	R 11.5	R 11	R 14	R 11	R 10
105-140	0.22-0.28	100	Inches	1.0	1.5	1.5	1.5	1.5
			R-value	R 7.7	R 12.5	R 11	R 9	R 8
Fluid Operating Temperature Range (°F)	**Insulation Conductivity: Conductivity (in Btu·in/h·ft^2·°F)**	**Insulation Conductivity: Mean Rating Temperature (°F)**		**Nominal Pipe Diameter (in inches): < 1**	**1 to <1.5**	**1.5 to < 4**	**4 to < 8**	**8 and larger**
Space cooling systems (chilled water, refrigerant and brine), and process cooling systems				**Minimum Pipe Insulation Required (Thickness in inches or R-value)[1]**				
40-60	0.21-0.27	75	Inches	Nonres 0.5 Res 0.75	Nonres 0.5 Res 0.75	1.0	1.0	1.0
			R-value	Nonres R 3 Res R 6	Nonres R 3 Res R 5	R 7	R 6	R 5
Below 40	0.20-0.26	50	Inches	1.0	1.5	1.5	1.5	1.5
			R-value	R 8.5	R 14	R 12	R 10	R 9

Footnote to Table 120.3-A:

1. These thicknesses are based on energy efficiency considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.

Exception 1 to Section 120.3: Factory-installed piping within space-conditioning equipment certified under Section 110.1 or 110.2.

Exception 2 to Section 120.3: Piping that conveys fluids with a design operating temperature range between 60°F and 105°F.

Exception 3 to Section 120.3: Where the heat gain or heat loss to or from piping without insulation will not increase building source energy use.

Exception 4 to Section 120.3: Piping that penetrates framing members shall not be required to have pipe insulation for the distance of the framing penetration. Metal piping that penetrates metal framing shall use grommets, plugs, wrapping or other insulating material to assure that no contact is made with the metal framing.

Exception 5 to Section 120.3: Fluid pumps, steam traps, blow-off valves, and piping within process equipment.

Exception 6 to Section 120.3: Valves, strainers, coil u-bends, and air separators with at least 0.5 inches of insulation.

Note**:** Authority: Sections 25213, 25218, 25218.5, 25402 and 25402.1, Public Resources Code. Reference: Sections 25007, 25008, 25218.5, 25310, 25402, 25402.1, 25402.4, 25402.5, 25402.8, and 25943, Public Resources Code.

SECTION 141.1 — REQUIREMENTS FOR COVERED PROCESSES IN ADDITIONS, ALTERATIONS TO EXISTING NONRESIDENTIAL, AND HOTEL/MOTEL BUILDINGS

Covered processes in additions or alterations to existing buildings that will be nonresidential, and hotel/motel occupancies shall comply with the applicable subsections of sections 110.2, 120.3, 120.6 and 140.9.

…

(d) **Process piping.** Piping for process heating or cooling systems shall meet the requirements in Section 120.3 if piping is:

1. Newly installed, or
2. Pipes are relocated as part of an alteration.

8.3 Reference Appendices

There are no proposed changes to the Reference Appendices.

8.4 ACM Reference Manual

There are no proposed changes to the ACM Reference Manual.

8.5 Compliance Forms

Compliance documents NRCC-PRC-E, NRCC-PRC-01-E, and NRCI-PRC-E would need to be revised. The revision would add pipe insulation verification to the forms.

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Appendix A: Statewide Savings Methodology

The Statewide CASE Team estimated statewide impacts for the first year by multiplying per-unit savings estimates by statewide construction forecasts that the CEC provided (California Energy Commission 2022). The CEC provided the construction estimates on March 27, 2023, at the Staff Workshop on Triennial California Energy Code Measure Proposal Template.

To calculate first-year statewide savings, the Statewide CASE Team multiplied the per-unit savings by statewide construction estimates for the first year the standards would be in effect (2026). The nonresidential new construction forecast is presented in Table 22 and nonresidential existing statewide building stock is presented in Table 23 (California Energy Commission 2023). The projected nonresidential new construction that would be impacted by the proposed code change in 2026 is presented in Table 22. (California Energy Commission 2023) The projected nonresidential existing statewide building stock that would be impacted by the proposed code change because of alterations in 2026 is presented in Table 23. (California Energy Commission 2023) This section describes how the Statewide CASE Team developed these estimates.

The CEC provided the nonresidential construction forecast, which is available for public review on the CEC's website: https://www.energy.ca.gov/title24/participation.html.

The construction forecast presents the total floorspace of newly constructed buildings in 2026 by building type and climate zone. The building types included in the CECs' forecast are summarized in Table 22.

The Statewide CASE Team made assumptions about the percentage of newly constructed floorspace that would be impacted by the proposed code change. Table 24 presents the assumed percentage of floorspace that would be impacted by the proposed code change by building type. If a proposed code change does not apply to a specific building type, it is assumed that zero percent of the floorspace would be impacted by the proposal. If the assumed percentage is non-zero, but less than 100 percent, it is an indication that some but not all buildings would be impacted by the proposal. Table 25 presents percentage of floorspace assumed to be impacted by the proposed change by climate zone. For existing buildings, it was assumed that 10 percent of the pipes are uninsulated. Based on stakeholder feedback from NAMIA, North American Insulation Manufacturers Association, and NIA, National Insulation Association, 10-35 percent of pipes in an average industrial facility are uninsulated pipes or have damaged insulation.

Table 22: Estimated New Nonresidential Construction in 2026 (Million Square Feet) by Climate Zone (CZ)

Building Type	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16	All CZs
Manufacturing	0.0009	0.0190	0.2708	0.1217	0.0298	0.0367	0.0510	0.1143	0.0132	0.0387	0.0000	0.0685	0.1181	0.0076	0.0081	0.0052	0.9037

Table 23: Estimated Existing Nonresidential Floorspace Impacted by Proposed Code Change in 2026 (Alterations), by Climate Zone and Building Type (Million Square Feet)

Building Type	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16	All CZs
Manufacturing	4.1097	17.3456	62.8404	79.7623	5.9763	73.7866	33.2933	123.1213	168.8865	50.2321	13.1229	59.1560	29.8770	17.1642	5.3399	9.4174	753.4316

Table 24: Percentage of Nonresidential Floorspace Impacted by Proposed Code Change in 2026, by Building Type

Building Type	New Construction Impacted (Percent Square Footage)	Existing Building Stock (Alterations) Impacted (Percent Square Footage)
Manufacturing	100%	10%

Table 25: Percentage of Nonresidential Floorspace Impacted by Proposed Measure, by Climate Zone

Climate Zone	New Construction Impacted (Percent Square Footage)	Existing Building Stock (Alterations) Impacted (Percent Square Footage)
1	100%	10%
2	100%	10%
3	100%	10%
4	100%	10%
5	100%	10%
6	100%	10%
7	100%	10%
8	100%	10%
9	100%	10%
10	100%	10%
11	100%	10%
12	100%	10%
13	100%	10%
14	100%	10%
15	100%	10%
16	100%	10%

Appendix B: Embedded Electricity in Water Methodology

There are no on-site water savings associated with the proposed code change.

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

There are no recommended revisions to the compliance software.

Appendix D: Environmental Analysis

Potential Significant Environmental Effect of Proposal

The CEC is the lead agency under the California Environmental Quality Act (CEQA) for the 2025 Energy Code and must evaluate any potential significant environmental effects resulting from the proposed standards. A "significant effect on the environment" is "a substantial adverse change in the physical conditions which exist in the area affected by the proposed project" (Cal. Code Regs., tit. 14, § 15002(g)).

The Statewide CASE Team has considered the environmental benefits and adverse impacts of its proposal including, but not limited to, an evaluation of factors contained in the California Code of Regulations, Title 14 section 15064 and determined that the proposal would result in a positive effect on the environment.

Direct Environmental Impacts

Improving insulation requirements for covered process pipes can reduce the amount of energy needed to heat or cool those pipes, which in turn can reduce greenhouse gas emissions from power plants that generate that energy. Additionally, improving insulation can reduce the amount of energy needed to heat or cool buildings, which can also reduce greenhouse gas emissions.

As discussed in Section 7.4, there would be an increase in insulation material use. In some cases, insulation materials themselves may have environmental impacts, such as the production and disposal of materials like fiberglass or foam insulation. Using more environmentally friendly materials, such as recycled or sustainable materials, can help mitigate these impacts though the code change proposal does not specify that recycled or sustainable materials be used.

Embodied Carbon in Materials

Accounting for embodied carbon emissions is important for understanding the full picture of a proposed code change's environmental impacts. The embodied carbon in materials analysis accounts specifically for emissions produced during the "cradle-to-gate" phase: emissions produced from material extraction, manufacturing, and transportation. Understanding these emissions ensures the proposed measure considers these early stages of materials production and manufacturing instead of emissions reductions from energy efficiency alone.

The Statewide CASE Team calculated emissions impacts associated with embodied carbon from the change in materials because of the proposed code change. The calculation builds off the materials impacts outlined in Section 7.4, see section for more details on the materials impact analysis.

After calculating the materials impacts, the Statewide CASE Team applied average embodied carbon emissions for each material. The embodied carbon emissions are based on industry-wide environmental product declarations (EPDs).[14,15] These industry-wide EPDs provide global warming potential (GWP) values per weight of specific materials.[16] The Statewide CASE Team chose the industry-wide average for GWP values in the EPDs because the materials accounted for in the statewide calculation has a range of embodied carbon. That is, some materials like concrete have a wide range of embodied carbon depending on the manufacturer's processes, source of the materials, and other factors. The Statewide CASE Team assumes that most building projects do not specify low embodied carbon products. Therefore, an average is appropriate for a statewide estimate.

First year statewide impacts per material (in pounds) were multiplied by the GWP impacts for each material. This provides the total statewide embodied carbon impact for each material. If a material's use is increased, there would be an increase in embodied carbon impacts (additional emissions). If a material's use is decreased, there would be a decrease in embodied carbon impacts (emissions reduced). Table 26 presents estimated first-year GHG emissions impacts associated with embodied carbon. The increased GHG emissions from embodied carbon are modest when compared to the 30,008 metric tons CO2e GHG emissions reductions from reduced energy use as presented in Section 7.2.

Table 26: First-Year Embodied Carbon Emissions Impacts

Material	Impact	First-Year Statewide Impacts (Pounds)	Embodied GHG Emissions Reductions (Metric Tons CO2e)
Insulation	Increase	3,812,344	(4,232)

[14] EPDs are documents which disclose a variety of environmental impacts, including embodied carbon emissions. These documents are based on lifecycle assessments on specific products and materials. Industry-wide EPDs disclose environmental impacts for one product for all (or most) manufacturers in a specified area and are often developed through the coordination of multiple manufacturers and/or associations. A manufacturer specific EPD only examines one product from one manufacturer. Therefore, an industry-wide EPD discloses all the environmental impacts from the entire industry (for a specific product/material) but a manufacturer specific EPD only factors one manufacturer.

[15] An industry wide EPD was not used for mercury, lead, copper, plastics, and refrigerants. Global warming potential values of mercury, lead and copper are based on data provided in a lifecycle assessment (LCA) conducted by Yale University in 2014. The GWP value for plastic is based on a LCA conducted by Franklin Associates, which capture roughly 59 percent of the U.S.' total production of PVC and HDPE production. The GWP values for refrigerants are based on data provided by the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report.

[16] GWP values for concrete and wood were in units of kg CO2 equivalent by volume of the material rather than by weight. An average density of each material was used to convert volume to weight.

Appendix E: Discussion of Impacts of Compliance Process on Market Actors

This appendix discusses how the recommended compliance process, which is described in Section 3.6, could impact various market actors. Table 27 identifies the market actors who would play a role in complying with the proposed change, the tasks for which they are responsible, how the proposed code change could impact their existing workflow, and ways negative impacts could be mitigated. The information contained in Table 27 is a summary of key feedback the Statewide CASE Team received when speaking to market actors about the compliance implications of the proposed code changes. Appendix F summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the code change proposal, including gathering information on the compliance process.

Table 27: Roles of Market Actors in the Proposed Compliance Process

Market Actor	Task(s) in current compliance process relating to the CASE measure	How would the proposed measure impact the current task(s) or workflow?	How would the proposed code change impact compliance and enforcement?	Opportunities to minimize negative impacts of compliance requirement
MEP Designer	Designers who issue specifications that include a table of insulation thicknesses would need to update their specifications to reflect new insulation thickness requirements.	Minor increase in requirement detail initially.	NRCC-PRC would need to be updated with new insulation requirements	Designer notes serve as a prompt to the General Contractor to anticipate verification coordination.
Contractor/ Installers	GC coordinates with trades for verification visits	Increased needs for coordination to time and schedule verification visits	NRCC-PRC would need to be updated with new insulation requirements	May need to change practices to allow clearance around the piping for the 2-inch thick insulation
AHJ	Perform verification for pipe insulation quality	Increase in observing and following requirement change initially.	NRCC-PRC would need to be updated with new insulation requirements	N/A

Appendix F: Summary of Stakeholder Engagement

Collaborating with stakeholders that might be impacted by proposed changes is a critical aspect of the Statewide CASE Team's efforts. The Statewide CASE Team aims to work with interested parties to identify and address issues associated with the proposed code changes so that the proposals presented to the CEC in this draft CASE Report are generally supported. Public stakeholders provide valuable feedback on draft analyses and help identify and address challenges to adoption including cost-effectiveness, market barriers, technical barriers, compliance and enforcement challenges, or potential impacts on human health or the environment. 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 2025 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 process load pipe insulation via webinar described in Table 28. 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 28: Utility-Sponsored Stakeholder Meetings

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
First Round of Nonresidential Industrial Insulation, Laboratories, Refrigeration, and Elevators Utility-Sponsored Stakeholder Meeting	Tuesday, January 31st, 2023	https://title24stakeholders.com/event/nonresidential-industrial-insulation-labs-refrigeration-and-elevators-utility-sponsored-stakeholder-meeting/

The first round of utility-sponsored stakeholder meetings occurred on January 31st, 2023 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 2025 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.

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 3,000 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 (and cross-promoted on the CEC 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.

Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email and phone with stakeholders when developing this report, listed in Table 29.

Table 29: Engaged Stakeholders

Organization/Individual Name	Market Role	Mentioned in CASE Report Sections
National Insulation Association	Industry Association	Appendix A
North American Insulation Manufacturing Association	Industry Association	Appendix A
Industrial Assessment Center	Industry Organization	No
Itron	Evaluation firm	Yes
Thermaxx	Insulation Contractor	Yes

Appendix G: Energy Cost Savings in Nominal Dollars

The CEC requested energy cost savings over the 30-year period of analysis in both 2026 present value dollars (2026 PV$) and nominal dollars. The cost-effectiveness analysis uses energy cost values in 2026 PV$. Costs and cost-effectiveness using and 2026 PV$ are presented in Section 6 of this report. This appendix presents energy cost savings in nominal dollars.

Table 30: Nominal LSC Energy Savings Over 30-Year Period of Analysis — Per 1,000 Square Foot — New Construction

Climate Zone	30-Year Lifecycle Electricity Cost Savings (Nominal $)	30-Year Lifecycle Natural Gas Cost Savings (Nominal $)	Total 30-Year Lifecycle Energy Cost Savings (Nominal $)
1	178.53	2,533.56	2,712.1

Table 31: Nominal LSC Energy Savings Over 30-Year Period of Analysis — Per 1,000 Square Foot — Alterations

Climate Zone	30-Year Lifecycle Electricity Cost Savings (Nominal $)	30-Year Lifecycle Natural Gas Cost Savings (Nominal $)	Total 30-Year Lifecycle Energy Cost Savings (Nominal $)
1	178.53	3,866.37	4,044.9