TITLE 24, PART 6 | 2028 CODE CYCLE

Process Boiler #1: Non-Condensing Stack Economizer Requirement

Codes and Standards Enhancement (CASE) Proposal

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CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

Proposal Description

- Code Change Proposal
- Benefits
- Background Information

Proposed Code Changes: Stack Economizers

1) This proposal would **require boiler stack (non-condensing) economizers** on **all new process boilers with input capacities at or above 10 MMBtu/hr**, including replacement boilers, with exemptions for:

   - Boilers with stack temperatures below 340°F at their lowest firing rate without an economizer.
   - Boilers that burn biofuels or hydrogen.
   - Boilers employing other methods of stack heat recovery, such as a heat exchanger that serves an industrial heat pump or process drying application.

See Title24stakeholders.com for proposal description, justification, draft code language, and requested data

Proposed Code Changes: Update to O_2 Trim

2) This proposal would **update existing Title 24, Part 6 code language** to allow excess oxygen concentrations for newly installed process boilers at or above 5 MMBtu/hr as follows:
   - Ultra-low NOx burners: maximum 7% excess O_2 at or above 20% of maximum fire.
   - Mesh burners: maximum 10% excess O_2 at or above 20% of maximum fire.
   - Boilers equipped with Selective Catalytic Reduction (SCR) systems: maximum 4% excess O_2 at or above 25% of maximum fire.

This proposal would not change the O_2 trim control exception for boilers with steady state full-load combustion efficiency of 90% or higher.

See Title24stakeholders.com for proposal description, justification, draft code language, and requested data

Poll

What is the lowest feasible percent of excess O_2 for boilers meeting the most stringent California AQMD NOx requirements?

Please list reasonable percentages for each specified boiler or burner type you are familiar with:

- Ultra-low NOx burners
- Mesh burners
- Boilers equipped with Selective Catalytic Reduction (SCR) systems

Benefits of the Proposed Changes

1) The use of a stack economizer is typically the **highest-impact action sites can take** to reduce their boiler natural gas usage.

- Stack economizers:
  - **Reduce load and thermal stress** on the boiler,
  - Lower fuel consumption (**saving 2-3% of fuel energy**), and
  - **Extend boiler useful life**.
- Additional benefits of this proposed code change include:
  - An **increase in jobs** to manufacture and install stack economizers
  - **Improved local air quality**
    - Many industrial facilities are located near Low- and Moderate-Income (LMI) housing, which is disproportionately exposed to lower air quality. This proposal would reduce photochemical smog in these communities.

"It's crazy that every boiler doesn't have [a stack economizer]."
– Boiler manufacturer

2) Updating the Title 24, Part 6 requirements to allow for oxygen concentrations higher than 3.0 percent would **enable boilers to comply with both Title 24, Part 6 and California's local air quality district requirements.**

Background Information: Stack Economizers

- Most steam boilers lose 20% or more of their input fuel energy in the form of combustion exhaust as hot flue gas exits the stack.
- A stack economizer is an assembly of finned tubing placed in the boiler exhaust stream which **recovers a significant fraction of the combustion waste heat** by pre-heating the boiler feedwater with the hot boiler flue gas.
- This **reduces load** on the boiler and **saves fuel**.
- The use of boiler stack economizers has been listed in Department of Energy literature as a **best practice since at least the early 2000s**.
- Despite its cost-effectiveness, this measure often goes unimplemented because of its first cost and a general lack of owner and operator awareness of the energy benefits.

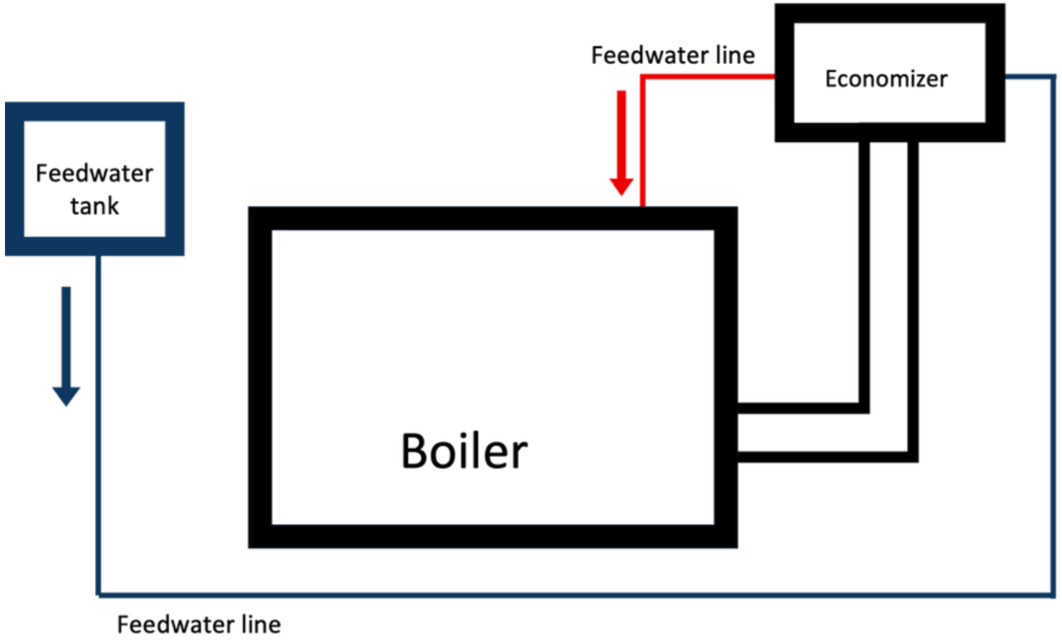

Diagram recreated based on image from: Electrical4U

Background Information: O_2 Trim Control

- 2025 Title 24, Part 6 requirements dictate that qualified boilers shall maintain stack-gas oxygen concentrations lower than or equal to 3.0 percent over specific firing rates.

- However, **low- NOx boilers that comply** with California's local air quality district emission limits **require higher amounts of excess oxygen**—often above 3.0 percent.
- Updating Title 24, Part 6 requirements to allow for oxygen concentrations higher than 3.0 percent would allow boilers compliant with California's local air quality district requirements to also comply with Title 24, Part 6.
- The proposed requirements would **account for different boiler types** that require different oxygen concentrations to maintain efficiency.
- Eliminating conflicting regulations through this proposal would **improve ongoing code compliance.**

Figure 10: Oxides of Nitrogen Emissions Results

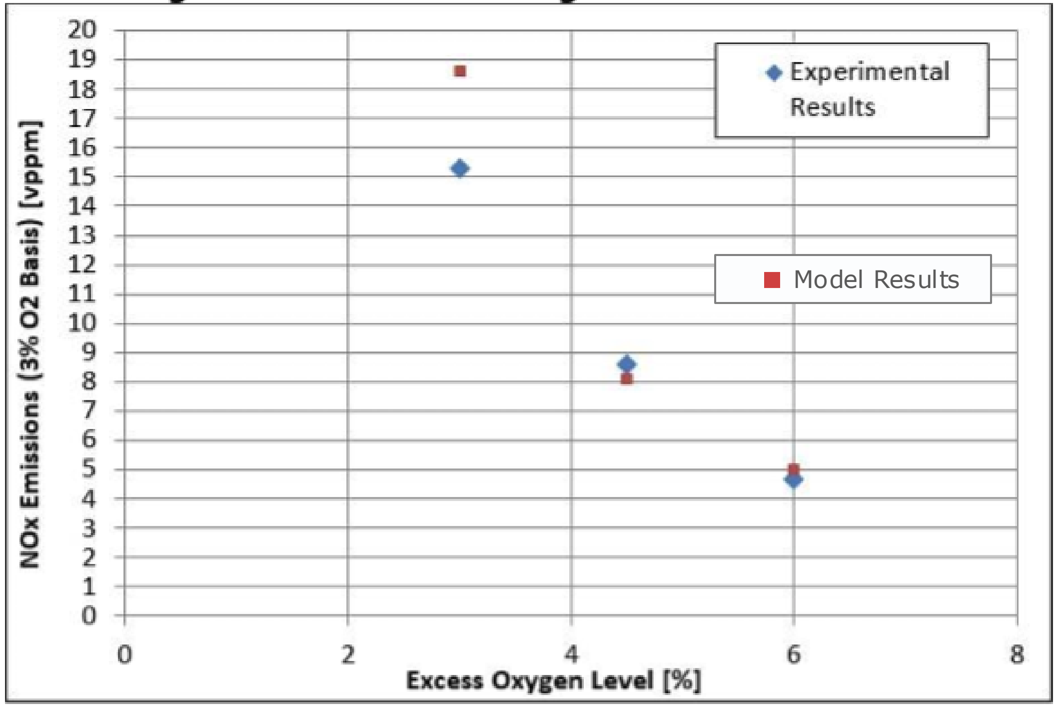

Image from CEC Project Report: Demonstration of a Novel Ultra-Low Oxides of Nitrogen Boiler for Commercial Buildings, 2021
Image source: Gas Technology Institute

Marked-up Code Language

See Title24stakeholders.com for marked-up code language

Title 24, Part 1	Title 24, Part 6	Reference Appendices
▪ No changes	▪ 100.1(b) Definitions ▪ 120.6 (d) Mandatory requirements for process boilers	▪ Nonresidential Appendix NA7 Installation and Acceptance Requirements for Nonresidential Buildings and Covered Processes ▪ NonRes and Multifamily Compliance Manual, Chapter 10, Section 10.9 Process Boilers

Market and Technical Considerations

- Current Conditions and Trends
- Potential Barriers and Solutions
- Technical feasibility

Current Market Conditions

1) In general, boiler system vendors and contractors are familiar with stack economizers and they are **widely available**.

- There are **multiple manufacturers** for all required equipment and components.
- Existing utility programs related to boiler economizers include:
  - A SoCal Gas Business Equipment Rebate for steam boiler stack economizers
  - A PG&E Technology Incentive for condensing economizers, which are a type of boiler economizer with even higher energy savings.
- Without the code change, the CASE team expects the prevalence of boiler stack economizers to remain relatively stable.

2) **O_2 trim control is already in** Title 24, Part 6 code.

SoCal Gas Rebate https://www.socalgas.com/business/savings/equipment-rebates
PG&E Incentive: http://www.pge.com/assets/pge/docs/save-energy-and-money/rebate-and-incentives/stack-gas-economizers-fact-sheet.pdf
Estimated rates of stack economizer installation by boiler size based on an analysis of IAC Audit Data from 64 in 32 steam-using industrial plants from 2010-2022.

Market Barriers and Solutions

Market Barriers

1. Stack economizers increase the first cost of a boiler, and the estimated 4- to 13-year payback period is longer than most facilities typically consider for investments.
2. Boilers burning hydrogen have higher costs and lower emissions than boilers burning other fuel.
3. Boilers that burn wood processing byproducts or other biofuels will have increased maintenance costs for stack economizers.

Potential Solutions

1. Market education and stakeholder outreach to improve awareness of economizer efficiency and payback periods.
2. Exemption for boilers that burn hydrogen to encourage adoption of hydrogen burning boilers.
3. Exemption for boilers that burn wood processing byproducts or other biofuels.

Current Market Share

Market share: percentage of boiler systems that already use a stack economizer

Current Estimated Market Share

New Boilers	35%
Existing Boilers	27%

Sources: Interviews with boiler manufacturers and Enesfere analysis of 37 steam-using sites in Northern and Central California audited between 2011 and 2022. 10 of 37 had a stack economizer on either only the primary boiler or on all boilers, resulting in a 27% current market share.

Poll

What do you think is the current market share of stack economizers for new boilers (including additions and replacements) in the range of 10 to 25 MMBtu/hr?
That is, what percentage of new boilers in California currently install stack economizers?

a. 1% – 10%
b. 11% – 20%
c. 21% – 30%
d. 31% – 40%
e. 41% - 50%
f. 51% - 60%
g. 61% - 70%
h. 71% - 80%
i. 81% - 90%
j. 91% - 100%

Poll

What do you think is the current market share of stack economizers for new boilers (including additions and replacements) in the range of 25 to 75 MMBtu/hr?
That is, what percentage of new boilers in California currently install stack economizers?

a. 1% – 10%
b. 11% – 20%
c. 21% – 30%
d. 31% – 40%
e. 41% - 50%
f. 51% - 60%
g. 61% - 70%
h. 71% - 80%
i. 81% - 90%
j. 91% - 100%

Poll

What do you think is the current market share of stack economizers for new boilers (including additions and replacements) over 75 MMBtu/hr?
That is, what percentage of new boilers in California currently install stack economizers?

a. 1% – 10%
b. 11% – 20%
c. 21% – 30%
d. 31% – 40%
e. 41% - 50%
f. 51% - 60%
g. 61% - 70%
h. 71% - 80%
i. 81% - 90%
j. 91% - 100%

Technical Considerations

Installation:

- Stack economizers can be installed in various configurations, making them feasible in most facilities. Their installation requires available space on the boiler stack. However, if there is not space in the boiler room, the stack economizer can be roof mounted.

Temperature and Climate:

- Stack economizers require high boiler stack temperatures to recover adequate heat. When boiler stack temperatures are below 340°F without an economizer, non-condensing stack economizers are not practical.
- Stack economizer feasibility and effectiveness is not impacted by boiler climate zones.

Maintenance:

- While stack economizers foul at a slower rate than boiler firetubes, fouling rates are still significant.
- This site maintenance item should be addressed during regularly scheduled maintenance.

Technical Barriers and Solutions

Technical Barriers

1. Boilers that have stack temperatures below 340°F are not suitable for non-condensing stack economizers.
2. Boilers that burn biofuels have high potential for fouling in the heat exchanger.
3. Some alterations may not have sufficient existing space to install a standard boiler plus stack economizer, which would necessitate a more expensive roof-mounted economizer.
4. When stack economizers foul, boiler operators may bypass the economizer instead of retubing them, which would reduce the measure's impact.
5. Different types of burners require different oxygen concentrations.

Potential Solutions

1. Exemption for boilers with stack temperatures below 340°F.
2. Exemption for boilers that burn biofuels.
3. Consider cost-effectiveness for sites where the building ceiling height or existing footprint shape results in insufficient room to install a standard boiler plzus stack economizer and create an exemption based on ceiling height if needed.
4. Take potential economizer bypass into account when calculating measure savings and recommend that sites address stack economizer fouling during scheduled periodic maintenance.
5. Specify separate maximums for ultra-low NOx burners, mesh burners, and boilers equipped with Selective Catalytic Reduction (SCR) systems.

Poll

What else should we know? Are there market or technical barriers or solutions we should consider?

Open ended response

Per Unit Energy and Cost Impacts

Methodology and Assumptions

- Energy and Energy Cost Savings
- Incremental Costs

Energy and Energy Cost Savings Methodology

Savings were calculated based on improved combustion efficiency due to the economizer recovering heat.

1) **Calculate baseline and post- combustion efficiency** using the ASME PTC-4 Indirect Method: Stack Loss Method*

Avg. stack temperature without stack economizer: 382°F, avg. stack temperature with stack economizer: 302°F

2) **Calculate boiler load** based on gas consumption and boiler efficiency

$$Boiler\ Load = \frac{Annual\ Gas\ Consumption_{Baseline}}{Boiler\ Efficiency_{Baseline}}$$

3) **Calculate baseline and proposed boiler gas consumption** based on boiler load and boiler efficiency

$$Annual\ Gas\ Consumption_{Post} = \frac{Boiler\ Load}{Boiler\ Efficiency_{Post}}$$

4) **Calculate difference in baseline and proposed gas consumption** to get energy savings

$$Savings = Annual\ Gas\ Consumption_{Baseline} - Annual\ Gas\ Consumption_{Post}$$

*See appendix slide for ASME PTC-4 Indirect Method: Stack Loss Method calculations

Note: preliminary savings calculations have not been conducted for the proposed code change related to O_2 trim, as that measure is anticipated to have minimal energy impacts.

Key Assumptions

Baseline

No stack economizer.

Proposed

Installed stack economizer.

<u>Consistent between baseline and measure case:</u>

1. Boiler operation: 6,500 hrs/yr
2. Shell losses: 1%
3. Combustion air temperature: 75°F
4. Stack O_2: 7.1%

<u>Unique to baseline case:</u>

1. Boiler efficiency: 79.5%
2. Combustion efficiency: 80.5%
3. Stack exhaust temperature: 382°F

<u>Unique to proposed measure case:</u>

1. Boiler efficiency: 81.8%
2. Combustion efficiency: 82.8%
3. Stack exhaust temperature: 302°F
4. Economizer heat transfer effectiveness: 95%

Incremental Cost Framework

Baseline

No stack economizer.

First Cost

1. None

30-Year Maintenance Costs

1. None

Proposed

Installed stack economizer.

First Cost*

1. Stack economizer first cost
2. Stack economizer installation cost

30-Year Maintenance Costs

1. Stack economizer retubing
2. O_2 trim tuning
3. 1 stack economizer replacement (15 year EUL)

*Incremental startup/commissioning costs are negligible.

Stack Economizer First Costs and Estimated Payback Period

Proposed

Installed stack economizer.

Boiler Size (MMBTU/h)	Stack Economizer Incremental First Cost* (parts and labor)	Boiler First Cost (parts and labor)	Stack Economizer Cost as a Percentage of Boiler Cost	Estimated Payback (Years)
12	$68,000.00	$350,000	19%	7-13
19	$98,000.00	$500,000	19%	6-11
33	$150,000.00	$800,000	19%	6-10
71	$240,000.00	$1.2 million	20%	5-10
143	$440,000.00	$2 million	22%	5-9
739	$1.1 million	$4 million+	≤28%	4-8

Natural gas cost: $0.90/therm.
Boiler size used for calculations is the mean of the estimated installed boilers in CA within the following size ranges: 10-15, 15-25, 25-50, 50-100, 100-200, 200+ MMBtu/h.
*Stack economizers that go directly on the stack. Roof economizer costs are higher, up to double the cost of the stack economizer on the boiler stack. Stack economizer cost data based on anonymized site data from field engineers for recent purchase and installation costs of the stack economizer. Boiler first costs are based on email correspondence with a boiler manufacturer. Installation costs are estimated to be 10-30% of estimated boiler hardware costs.

Approach for Gathering Costs

- The CASE team plans to:
- Conduct interviews with boiler stack economizer manufacturers, distributors, and installers to collect data on:
  - **the purchase and installation costs** of non-condensing stack economizers across boiler sizes
  - the **lifetimes, maintenance frequency**, and **maintenance costs** of stack economizers, including economizer retube costs
- Interview boiler plant operators and maintenance staff to gather data on the **lifetimes, maintenance** frequency, and **maintenance costs** of stack economizers
- Evaluate economizer lifetime data from the CPUC DEER database and eTRM website
- Review economizer cost data in RSMeans Mechanical Cost and RSMeans Labor Rate datasets
- **The CASE team is looking for information on the first costs, installation costs, and annual maintenance costs for non-condensing stack economizers and O2 trim control.**

Compliance Verification

- Key Aspects of Compliance Verification
- Barriers and Solutions
- Revisions to Compliance Software

Key Aspects of Compliance Verification

New compliance verification steps for this measure will consist of the following:

- **Design document review** by AHJ plan checkers to ensure planned installation of a stack economizer.
  - To qualify for the stack temperature exception, the mechanical schedule must include a qualifying stack temperature at lowest fire.
  - To qualify for the fuel exemption, the construction drawings must show the biofuel line (fuel piping) for boilers with liquid or gaseous fuels or show a conveyer for solid fuels.
  - To qualify for the heat recovery exemption, confirm planned installation of stack heat recovery equipment.
- **Acceptance testing performed by a field technician** on all new qualifying process boilers to:
  - ensure that the stack economizer is operational and not bypassed at time of testing, or
  - confirm the stack temperature at lowest fire is below 340°F for boilers that are pursuing the stack temperature exception.
  - confirm operational stack heat recovery equipment for boilers that are pursuing the heat recovery exception.
- Updates to **compliance forms**:
  - Add the stack economizer requirement to the Certificate of Compliance form (NRCC-PRC-E)
  - Add the stack economizer requirement to the Process System Certificate of Installation form (NRCI-PRC-E), including verification of exceptions as applicable.
  - Add the stack economizer requirement to a new Nonresidential Certificates of Acceptance form (NRCA-PRC-18

Compliance Barriers and Solutions

Compliance Verification Barriers	Potential Solutions
1. AHJ plan checkers and field technician must be comfortable checking for a stack economizer in design documents and evaluating whether a stack economizer is bypassed.	1. The CASE team will support comprehensive AHJ training on stack economizer requirements and add supporting information to the Nonresidential Compliance Manual (10.9).

Compliance Software Updates

No software updates required. CBECC currently does not cover boiler measures.

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More information on
CEC's 2028 proceeding website.

We want to hear from you!

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Note on Thermal Fluid Heaters

Thermal fluid heaters, defined by AQMD.gov as a natural gas fired process heater in which a process stream is heated indirectly by a heated fluid other than water, are excluded from all 2028 covered process boiler measures.

ASME PTC-4 Indirect Method: Stack Loss Method

This method approximates the stack losses of a boiler to estimate boiler efficiency.

Parameters

The parameters needed to calculate this method are given below. These data are calculated during source testing.

1. Stack temperature (T_{Stack})
2. Dry oxygen in flue gas ($O_{2,Dry,\%}$) in percent

Assumptions

The assumptions used in this calculation are the following:

1. One percent energy loss from radiation and surface convection.
2. Loss associated with carbon monoxide in flue gas is negligible.
3. Loss associated with moisture in fuel is negligible.
4. Loss associated with moisture in air is negligible.

Summary of Calculations

Calculation of mass of dry gas per standard cubic feet of fuel:

$$DG = 14.7365\left(\frac{O_{2\%}}{21\% - O_{2\%}}\right) + 15.371$$

Calculation of Dry Losses in stack:

$$L_{DG}[\%] = 0.001044 \times DG \times (T_{Stack} - 70)$$

Calculation of Wet Losses in stack:

$$L_{WG}[\%] = 9.482 + 0.004351 \times T_{Stack}$$

Boiler Efficiency:

$$BE = 100\% - L_{DG} - L_{WG} - 1\%_{Other\ Losses}$$