Boiler Burner Retrofit Technoeconomic Analysis (TEA)

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ICF is responsible for this project. This project, ET24SWG0011, was developed as part of the Statewide Gas Emerging Technologies Program (GET) under the auspices of SoCalGas as the Statewide Lead Program Administrator. Anoushka Cholakath conducted this technology evaluation with overall guidance and management from Steven Long. For more information on this project, contact Steven.Long@ICF.com.

Disclaimer

Abbreviations and Acronyms

Abbreviations and Acronym Heading	Abbreviations and Acronym Heading
TRC	Total Resource Cost
TSB	Total System Benefit
ULN	Ultra Low NOx
NZN	Near Zero NOx
CET	Cost Effectiveness Tool

Executive Summary

The purpose of this project was to conduct a brief technoeconomic analysis for boiler burner retrofit applications, leveraging results from the recently completed GET project ET23SWG0009 Ultra Low NOx Burner Testing.

This project modeled energy savings based on a commercial 125HP boiler using data from ET23SWG0009. The estimated annual customer savings based on fuel consumption was $11,766 for the emerging energy efficient technology operating at a sub-9 ppm NOx level and $8,204 per year for the emerging energy efficient technology operating at a sub-2.5 ppm NOx level. Customers can also save on emissions fees by upgrading to these more energy efficient technologies that also fully comply with some of California's strictest air quality standards[1]. The study noted that higher upfront costs may be a barrier preventing customers from switching to this new technology. This project also examined the feasibility of offering a boiler burner retrofit as a potential measure offering, which could result in an incentive structure for customers to switch to these newer burners.

The study leveraged existing boiler measure packages and utilized the Cost Effectiveness Tool (CET) on the California Energy Data and Reporting System (CEDARS) to determine the Total Resource Cost (TRC) and Total System Benefit (TSB) of a potential boiler burner retrofit measure. The savings were determined based off the previous GET ET23SWG009 study and the CET tool provided a TRC of 1.89 and TSB of $7,398. Given that the TRC is greater than 1, this is generally considered a feasible measure package to pursue. The study recommends that further research be conducted using the RS Means database or other reliable data sources to investigate baseline burner costs and a more accurate payback period.

[1] Some AQMDs base annual emissions fee on partial compliance.

Introduction

Nitrogen Oxide (NOx) emissions standards in California are among the strictest in the nation. Various NOx controlling equipment to help meet these standards is needed for larger boilers and process heaters. The GET Program had previously completed project ET23SWG0009 Ultra Low Nox Burner (ULN) Field Testing where the project team tested the emissions and efficiency improvements of the emerging ClearSign Rogue Ultra Low Nox boiler burner technology compared to typical baseline mesh Ultra Low Nox burners. The goal of this project ET24SWG0011 is to leverage the data from the previous project to perform a Technoeconomic Analysis to evaluate the feasibility of energy efficient burner technologies as a measure offered in California by determining the TRC and TSB.

Methods

There are several boiler measure packages on the California statewide Electronic Technical Reference Manual (eTRM) including Commercial, Multifamily, and Process boilers for service and hot water needs. Energy efficient boilers included within the SWWH008 Process Boiler measure can have one or more of the following: forced air burner, large heat exchanger surface, and/or an economizer to utilize heat recovery from stack gases. Energy Efficient burners with ultra-low NOx capabilities also have the ability to improve the overall boiler operating efficiency as established in ET23SWG0009. These next-generation energy efficient ultra-low NOx burners are able to reach Near-Zero NOx (NZN) levels while also maintaining high levels of operating efficiency compared to traditional ULN burner technologies.

A separate measure package could be developed to target boiler burner retrofits. This could help support California's large commercial and industrial boiler customers by adding energy efficient and ultra-low NOx burners into the measure portfolio to help incentivize the adoption of the newer technology. However, in order to determine the feasibility of offering an energy efficient burner as a new measure, the estimated TRC and TSB needs to be calculated. To do this, this study leveraged the Cost Effectiveness tool (CET).

Cost Effectiveness Tool

This study selected the following CET selections, referencing specific inputs and characteristics of the SWWH008 boiler measure. The selections are summarized in Table 1.

Table 1. CET Input Selections

Category	Selection
Proposed Measure Name	Energy Efficient ULN Burners Boiler Retrofit (Leveraged existing offer IDs E and F for the approach)
Proposed Offering IDs	1. Energy Efficient ULN Burner Retrofit, <=125HP, Sub 9ppm 2. Energy Efficient NZN Burner Retrofit, <=125HP, Sub 2.5ppm
Use Category	ProcHeat: Process Heat
Use Sub Category	SteamDist: Steam Distribution
Technology Group	SteamHtg_eq: Steam Heating Equipment
Technology Type	Boiler_AF: AFUE Rated Boiler
Building Type	Any; Normal replacement offered for all existing building vintages.
Climate Zone	This measure is applicable in all California climate zones
Sector	Agricultural, Commercial, Industrial
Measure Application Type	Normal Replacement
Normalized Unit	Cap-kBTUh; same as boiler measures
EUL	20 years

CET Calculations

To determine the savings, the following calculations were completed based on SWWH008 boiler measure. The average efficiencies and fuel energy used from previous study in project ET23SWG0009 for the baseline burner technology and the ClearSign Rogue burner at sub 9 ppm and NZN mode at a 66% firing rate were used for the calculations[2].

Equation 1: Annual Unit Energy Savings – Gas

$$\boldsymbol{UEC\_YrThermBase - UEC\_YrThermMeas}$$

Where:

UEC_YrThermBase = Annual unit energy consumption - gas, baseline (therms/yr)
UEC_YrThermMeas = Annual unit energy consumption - gas, measure case (therms/yr)

Equation 2: Annual Unit Energy Consumption – Gas, Baseline

$$\boldsymbol{\frac{(const\_oprHrsPYr \cdot const\_capFacProAvg)}{CFac\_kBtu\_therm}}$$

Where:

const_oprHrsPYr = Annual operating hours (hr/yr)
const_capFacProAvg= Average capacity factor across all industries (no units)
CFac_kBtu_therm = kBtu per therm

The weighted average capacity factor provided by SWWH008 was used for calculations.

Equation 3: Annual Unit Energy Consumption – Gas, Measure Case

$$\boldsymbol{UEC_{YrThermBase} \times \left(\frac{constCombustEff\_baseEff}{constCombustEff\_measEff}\right)}$$

Where:

UECbase_YrTherm = Annual unit energy consumption - gas, baseline (therm/yr)
constCombustEff_baseEff = Base case efficiency (%)
constCombustEff_measEff = Measure case efficiency (%)

The two proposed measure offering IDs that were developed are described as:

1. Energy Efficient ULN Burner Retrofit, <=125 HP, Sub9 ppm
2. Energy Efficient NZN Burner Retrofit, <=125 HP, Sub 2.5 ppm

Table 2 summarizes the calculations from equations 1-3.

[2] The 66% test rate data was used for both base and measure cases and is assumed to be a "typical" operating range. Measure package assumptions for operating hours and annualized firing rate were used.

Table 2: Calculated values from Equations 1-3

	Annual Unit Energy Consumption (therm/year-KBtu Cap)	Annual Unit Energy Savings (therms/year-KBtu Cap)
Baseline Burner	**70.18**	**n/a**
ClearSign Rogue Sub 9 ppm NOx – Measure Case	**67.14**	**3.03**
ClearSign Rogue Sub 2.5 ppm NOx – Measure Case	**68.06**	**2.12**

To calculate annual savings, the formulas from the SWWH008 Process Boiler measure package were used.

Equation 4: Incremental Cost in USD

$$(\boldsymbol{costs\_laborMeas} + \boldsymbol{costs\_mtlMeas}) - (\boldsymbol{costs\_laborBase} + \boldsymbol{costs\_mtlBase})$$

Where:

Costs_laborMeas: Measure case cost for installation labor
Cost_mtlMeas: Measure case cost for boiler burner system
Costs_laborBase: Base case cost for installation labor
Costs_mtlBase: Measure case cost for baseline burner

The ClearSign Rogue team provided a preliminary labor and measure cost estimate for the measure case burner, which is representative of the 125 HP burner used in project ET23SWG009. The baseline burner costs, and installation labor estimates were determined by web scraping. In addition to web scraping, the project team attempted to contact the baseline burner manufacturers for costs as well, but did not get specific prices for the purposes of this study. The project team recommends leveraging RS Means database to determine labor costs or other reliable database sources in the future for additional measure package development efforts.

After calculating the incremental measure cost from Equation 4, the normalized measure cost per kbtu Cap, and end-user rebate can be determined. The costs are summarized below in Table 3.

Table 3: Incremental and Measure Costs

	Incremental Measure Cost from Eq 4. ($)	Measure Cost normalized to ($/KBtu Cap)	End User Rebate ($/KBtu Cap)
ClearSign Rogue Sub 9 ppm NOx – Measure Case	$ 107,466.00	$ 20.55	$ 10.27
ClearSign Rogue Sub 2.5 ppm NOx – Measure Case	$ 157,592.00	$ 30.13	$ 15.07

As an estimate, the basis for the end user rebate is calculated to be 50% of the normalized measure cost for CET evaluation purposes. Using this information, the Measure and Program Cost files were developed and uploaded into the CET.

Portfolio Budget Filing Summary

Sector	Total System Benefit	TRC	PAC	TRC (no admin)	PAC (no admin)	RIM	Budget
Portfolio	$7,398	1.89	2.27	1.89	2.27	2.15	$3,649

Figure 1. CET Output

The CET output for the TRC is 1.89 and the TSB is $7,398 for a Normal Replacement retrofit in a process boiler ignoring admin costs. Note that these CET outputs are based on both proposed offering ID's and represent an average TRC and TSB value for multiple delivery types. Given that the TRC is greater than one, it is generally considered feasible and profitable for Program Administrators to develop a measure package centered around energy efficient boiler burner retrofits.

Customer Savings

In addition to improved emissions and efficiency gains from switching to a measure-case boiler burner, customers can save on reduced natural gas consumption and avoid emissions fees if their boiler is not fully compliant with Air Quality Management District (AQMD) NOx standards. Depending on the size of the equipment, and the AQMD jurisdiction, NOx emissions standards can range from 15 ppm to under 5 ppm. The South Coast AQMD Rule 1146, has NOx emissions limits set to 9 ppm NOx or below for commercial steam boilers and process heaters. Thus, establishing a basis for a state-wide measure package may be challenging unless the measure offering is for just the 2.5 ppm NOx burner. However, a custom approach for a boiler burner retrofit depending on the location of the equipment may be worth investigating, especially since certain jurisdictions have emissions fees for exceeding NOx limits. The impact of project influence relative to full compliance is unclear as the boiler could be run "as-is" by paying fees.

Some example burners retrofit scenarios are provided by ClearSign and Rogue Combustion below:

1. The Sub 9 burner serves as a direct replacement for mesh burners currently operating under sub-9 ppm NOx requirements. Its key advantage lies in energy and cost savings through reduced natural gas consumption.
2. In the San Joaquin Valley, many mesh burners operating at 5-9 ppm NOx are installed on 125-475 hp boilers under grandfathered permits. These permits require companies to pay emissions fees for operating above 5 ppm (San Joaquin Valley Air Pollution Control District, 2020). Upgrading to the sub-9ppm or sub-2.5 ppm burner allows businesses located in stricter AQMD districts to achieve improved efficiency and avoid fees, reducing ongoing operational costs.
3. The San Joaquin Valley also has numerous mesh burners operating at 2.5-9 ppm NOx on boilers exceeding 500 hp, similarly under grandfathered permits. These companies face emissions fees for operating above 2.5 ppm. Replacing these burners with an NZN burner offers enhanced efficiency and elimination of fees while avoiding the higher capital and operating costs associated with competing technologies, such as Selective Catalytic Reduction (SCR) systems. The additional savings from switching to a boiler burner replacement compared to costlier SCR system upgrades to meet NOx standards could also be determined by a custom approach using SCR as the baseline technology.

Savings and payback:

Leveraging GET study ET23SWG0009, the maximum annual savings at 100% firing rate can be calculated, assuming an average energy cost of $0.90/therm and natural gas fuel heating value of 100,000 BTU/therm. (US DOE, 2024).

Table 4. Annual Energy Savings

	Annual Fuel Costs ($)	Annual Savings ($)
Baseline	272,140	–
ClearSign Sub 9	260,374	$ 11,766
ClearSign Sub 2.5	263,936	$ 8,204

Customers can expect fuel savings of approximately $11,766 annually, and $235,313 over the 20-year EUL period from switching to an energy efficient burner operating at sub-9 ppm NOx. Annual savings of $8,234 are projected for the Sub 2.5 ppm burner which corresponds to $164,077 savings over the 20-year EUL period. A simple customer payback period based solely on fuel savings was calculated to be 9.1 years from switching to a sub-9 ppm energy efficient burner and 19.2 from switching to a sub-2.5 ppm burner. However, these numbers are draft and conservative since additional savings need to be factored into the measure burner cost savings in areas where customers are spending thousands of dollars on annual emissions fees for failing to meet NOx emissions targets. Additionally, the costs for calculating the payback period for the baseline technology need to be investigated further from databases like RS Means or by obtaining manufacturer quotes beyond web scraping. Furthermore, a custom pathway should be investigated for boiler burner retrofit applications given the various AQMD requirements and fee structure for NOx emissions. Cost benefits from switching to more efficient burners as opposed to SCR could also be factored into the overall customer savings and payback.

Conclusions

The results from this study found that newer, more efficient ultra-low NOx burners have high annual savings of upwards of $11,766/year in terms of fuel costs for a 125 HP burner retrofit. Larger boiler burners could see even higher fuel savings from switching from a typical metal mesh-burner to a more energy-efficient burner. However, investment costs may be a barrier for customers to make the switch. Thus, it is recommended that a measure package be developed to create an incentive structure around the newer burner technologies. The results from the CET validated the feasibility of such a measure package to be pursued in the future.

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