

Amnesty for Ancient Boilers

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ABSTRACT

The San Francisco Boiler Systems Incentive Program (“Boiler Program”) was an incentive-based energy efficiency program administered by the City and County of San Francisco’s Department of the Environment using two million dollars of its Federal Stimulus funds from the American Recovery and Reinvestment Act (ARRA) to promote the replacement of inefficient hot water and low-pressure steam boilers located in multifamily (MF) properties. Many of these properties have original boilers as old as the buildings themselves that date back to the early 1900s. The primary barrier to retrofitting an ageing heating system is the high up-front cost of the project. This program provided financial assistance to the property owner through financial incentives along with no-cost technical assistance to identify and implement energy efficiency measures for hot water heating and space heating. San Francisco (“the City”) has adopted long-range plans to make it more environmentally sustainable by developing initiatives that promote clean energy and reduce carbon emissions. As part of those efforts, the Boiler Program is expected to significantly reduce natural gas usage by incentivizing a variety of heating system measures such as hydronic and low-pressure steam heating boilers, water heaters, thermostatic radiator valves (TRVs), steam traps, air vents, pipe insulation, radiators and thermostats. This report presents the data that was collected during the course of the Program, such as the types and sizes of boilers replaced, the methods used to determine the energy savings, and the verified savings that resulted. It also presents the challenges and solutions that were addressed during the course of the Program.

Introduction

San Francisco has the highest concentration of MF buildings in California. Approximately 68.5% of the housing stock in the City are MF buildings, while the remaining 31.5% are single family homes. This trend is nearly reversed in the rest of the state and nation (U.S. Census Bureau, 2010). Many of the older central heating systems in these buildings are antiquated, unreliable, and inefficient. In an effort to promote energy efficiency in this market, over the past four years the Department of the Environment has been administering the San Francisco Energy Watch Multifamily Program. This program, funded by ratepayers through the local Investor Owned Utility (IOU) – Pacific Gas & Electric (PG&E), offers financial incentives to MF property owners for the installation of eligible energy efficiency measures (EEMs) such as pipe insulation, boiler controls, and hot water boiler replacements, yet excludes space heating low-pressure steam boilers (CCSF, 2010). However, many of the central heating systems in these buildings still utilize steam for space heating. Furthermore, many of these old boilers tend to be utilized far beyond their life expectancy, evidenced by the prevalence of boilers as old as 100 years found during our heating system audits. Taking into account the changes in current codes, air quality regulations, asbestos, and the high cost of labor, equipment, and material, replacing an old boiler can be very expensive; therefore, owners often prefer to maintain and repair these

boilers rather than replace them. Furthermore, under California Public Utility Commission (CPUC) regulations, IOU ratepayer funded energy efficiency programs do not allow for sufficient incentives to capture the efficiency opportunities that exist in thousands of ancient boilers that continue to operate in old buildings. For example, the Energy Watch Multifamily Program can only provide financial incentives for the increment of efficiency above the minimum efficiency requirements mandated by the Public Utilities and Energy Code, Title 20, California Code of Regulations. This restriction provides no incentive for the additional energy savings saved by replacing older inefficient boilers that operate well below these minimum efficiency requirements, nor does it provide incentives to bring systems up to code and comply with Bay Area Air Quality Management District (BAAQMD) regulations. When ARRA was signed into law in 2009, the City received a portion of this grant to implement energy efficiency programs to serve and stimulate the local economy. Knowing that there was an opportunity to go above and beyond the Energy Watch Program, the Department of the Environment was eager to implement a boiler program targeting the local MF market to provide sufficient incentives to include an expanded list of EEMs (e.g., steam heating measures). This program was designed to provide MF property owners financial assistance with the initial upfront capital expense of replacing an aging heating system, while stimulating the local economy by creating well-paying green jobs, bringing heating systems up to code, and reducing energy consumption and greenhouse gas emissions.

Funding

The American Recovery and Reinvestment Act of 2009 (ARRA) commonly referred to as “the Stimulus” or “The Recovery Act,” was an economic stimulus package enacted by the 111th United States Congress in February 2009 and signed into law on February 17, 2009, by President Barack Obama. To respond to the late-2000s recession, the primary objective for ARRA was to save and create jobs almost immediately. Secondary objectives were to provide temporary relief programs for those most impacted by the recession and invest in infrastructure, education, health, and ‘green’ energy.

ARRA appropriated \$3.2 billion for the Energy Efficiency and Conservation Block Grant (EECBG) Program. The EECBG funding supports energy audits and energy efficiency retrofits in residential and commercial buildings, the development and implementation of advanced building codes and inspections, and the creation of financial incentive programs for energy efficiency improvements. As a recipient to this Grant, the City and County of San Francisco’s Department of the Environment allocated approximately two million dollars towards retrofitting multifamily property heating systems in an incentive based energy efficiency program coined “The San Francisco Boiler Systems Incentive Program.”

Goals

The City and County of San Francisco has adopted long-range plans to make San Francisco more environmentally sustainable by developing initiatives that promote clean energy and reduce carbon emissions. As part of those efforts, the EEMs installed under the Boiler Program are expected to reduce natural gas usage by approximately 250,000 Therms per year

and Green House Gas Emissions by 1,330 Metric Tons of CO₂e per year. The program's goals included:

Benefits to the environment and citizens:

- Stimulate the local economy and provide jobs
- Reduce energy use green house gas emissions
- Improve air quality and mitigate respiratory disease
- Enhance San Francisco's reputation as a leader in environmental sustainability

Benefits to multifamily property owners:

- Reduce upfront cost to replace an existing inefficient and unreliable boiler
- Reduce operating, maintenance, and repair costs
- Reduce Heat Ordinance violations and complaints
- Reduce natural gas consumption, therefore reducing monthly utility bills
- Increase reliability and satisfy the comfort of tenants and occupants
- Meet new state and local code requirements with an updated, code-compliant system
- Meet the newly adopted BAAQMD Regulation 9 Rules 6 & 7 air quality regulations for boiler emissions

Benefits to local boiler/mechanical contractors:

- Increase sales and volume of work to maintain operations during economic downturn
- Create and/or save prevailing wage jobs
- Potential to establish new customer relationships and revitalize past ones

Neighborhoods and their Multifamily Buildings

Many of the MF buildings in need of financial assistance are prewar era single room occupancy (SRO) residential hotels, which exemplify historical and architectural interest to San Francisco's unique and diverse neighborhoods. These MF buildings house the local community that is as diverse as its architecture. Many senior citizens, low income, physically- and mentally-challenged tenants occupy these buildings, many of which are concentrated in the economically-challenged Tenderloin neighborhood.

Another category of MF buildings was built in the postwar era primarily in the 1950s and 1960s. While these buildings lack the architectural aesthetics of prewar era architecture, they included modern heating systems, such as hydronic (hot water) space heating and designated domestic hot water heating systems. Though an upgrade to the low-pressure steam heating systems commonly found in prewar era buildings, these hot water systems have also surpassed their expected service life and are an opportunity for replacement.

An example of pre/post-war era multifamily buildings can be seen in Figures 1 and 2.



Figure 1.
Prewar Era Multifamily Property
Year Built 1910
Low-pressure steam used for space heating



Figure 2.
Modern Multifamily Property
Year Built 1978
Hydronic heating used for space heating

Existing Heating Systems – an opportunity for improvement

Before participating in the Boiler Program, a heating systems audit and pre-installation inspection was conducted by Department of the Environment staff on the prospective building. During these audits, we found that many of the existing heating systems were as old as the buildings themselves dating back to the early 1900s, built just after the great 1906 San Francisco Earthquake and Fire. A classic method of providing space heat and domestic hot water (DHW) was with a low-pressure steam firebox boiler (e.g., Kewanee, Fitzgibbons boilers), which at the time were heated with oil. The first energy efficiency phase took place back in the 1940s-1950s converting these boilers from oil to natural gas. Today, most boilers in San Francisco are heated with natural gas except for applications that may require dual fuel (e.g., hospitals, SFO airport, etc.). Also during the heating system audits, we found that the overwhelming majority of the space heating systems in these older buildings are one-pipe low-pressure steam systems. Some of these boilers are operating twenty four hours a day to maintain the water in the boiler at 180-°F to provide DHW heating to a single wall instantaneous heat exchanger submerged in the boiler water just below the steam line. These boilers, providing both space and DHW heating, were sized for both loads at peak demands. This approach often led to over-sized boilers with respect to today's sizing methodologies. Newer construction that dates back to the 1950's and 1960s introduced more contemporary systems such as hydronic space heating and designated DHW systems independent of the space heating system.

The San Francisco Housing Code requires that all MF buildings maintain the temperature in occupied apartment units at a minimum of 68-°F for 13 hours a day between 5 am to 11 am and 3 pm and 10 pm. This code requires a time clock and a remote mounted thermostat located in a centrally located apartment unit (CCSF, 2007). During our audits, we found that many of these buildings either didn't have a thermostat or it was inoperable or disconnected, leaving a simple mechanical time clock to control the boiler's operation. This frequently resulted in overheated buildings, which often led to the practice of "opening windows" to control space temperature – clearly a waste of energy.

At one time, asbestos was the material of choice to insulate heated pipes. In many cases, the asbestos was abated during a transfer of sale. Unfortunately, the pipes were rarely reinsulated with fiberglass insulation – another major energy efficiency opportunity.

Contractors – a business opportunity

A number of local small-business boiler/mechanical contractors have thrived in this unique MF market providing preventative maintenance, repair, and replacement services. Many of these contracting firms specialize in steam heat and have passed on their expertise from generation to generation. The Boiler Program provided them with an opportunity to establish new customer relations and renew prior ones.

Challenges and Solutions

The implementation of the Boiler Program faced and overcame many challenges, to include enforcing prevailing wage labor rates and upgrading to current local codes and air quality regulations. The Recovery Act specifically requires that all laborers and mechanics employed by contractors and subcontractors on any project "funded directly by or assisted in whole or in part by" Recovery Act funds be paid Davis Bacon Act (DBA) wages as determined by the Secretary of Labor. In the State of California, if a project is funded or partially funded by the Federal government, then State of California prevailing wage labor rates must be paid if they exceed DBA wage rates (State of California, 2012). The prevailing wage rates in the County of San Francisco are higher than the DBA wage rates and therefore had to be paid by participating contractors. This was a uniquely challenging requirement. The program was designed to incentivize or otherwise subsidize up to 25% of the total cost of a project for privately owned buildings in the private sector. Prevailing wage rates in the past were only required for municipal or public works projects funded exclusively by government funds. Some of the local boiler/mechanical contractors are signatory to the local United Association of Journeymen Plumbers and Steamfitters Union and were already paying prevailing wage rates. However, many of the local contractors are smaller non-union shops paying lower rates. On one hand, requiring these labor rates leveled the playing field between the union and non-union shops. On the other hand, many of the non-union shops refused to participate in the Program due to this requirement. Additionally, as a result of the higher labor rates, some participating contractors found themselves increasing their bids which put them at a disadvantage when bidding against non-participating contractors. Therefore, the incentive structure was adjusted (increased) to subsidize these labor costs. Once the Program gained popularity, a balanced mix of both union and non-union companies participated.

Another challenge was retrofitting older equipment with new equipment that complied with current plumbing/mechanical codes and the BAAQMD air quality regulations. Most of the boilers in older MF buildings are located in a basement. Typically, these boilers are package firebox boilers with atmospheric burners that were set in place and the buildings were erected above them. The boiler stacks were run in brick-set chimneys; flue gas condensation or positive pressure power burners were not taken into consideration.

New high efficiency condensing hot water boilers require stack material (i.e., AL294C stainless steel, CPVC, or PVC) suitable for the corrosive nature of flue gas condensate. Reutilizing the existing brick-set chimneys was not an option. Per BAAQMD Regulation 9 Rule 6, low-pressure steam boilers exceeding 400 Btu/Hr input require Low NOx burners. These burners typically are “forced draft” power burners which in turn require positive-pressure stacks.

The issues with the stacks had an effect on the number of condensing boilers installed. If a hot water boiler was located on a roof, installing a stack suitable for condensate could easily be accomplished at minimal expense. If the boiler was located at ground level, side-wall venting was an option; however, many buildings in San Francisco are attached by the sides and the option of side wall venting was not feasible. The other option was to run a new stack on the outside of the building but this would be expensive and had aesthetic concerns. These issues frequently led to the installation of non-condensing fan assisted boilers. Fortunately, this style of boiler can still reach up to 85% efficiency without condensing and outperform the baseline equipment.

The Program

The Boiler Program was developed with the contractor in mind and an effort was made to make the Program user friendly. A list of energy efficiency measures (EEMs) were identified that would provide energy efficiency improvements to an ageing heating system. They included:

Eligible Energy Efficiency Measures that qualified for incentives:

- Low-pressure steam boilers (ASME, Section IV Heating Boilers) – space heating
- Heating hot water boilers (ASME, Section IV Heating Boilers) – space heating
- Domestic hot water boilers / water heaters – potable water heating
- Hot water heaters (≥ 30 gallon storage) – potable water heating
- Pipe and tank insulation
- Thermostats and time clocks
- Thermostatic radiator valves (TRVs) – steam and hot water space heating
- Air vents – radiator, high point hot water, and steam/condensate distribution headers
- Steam traps – thermostatic, float and thermostatic, inverted bucket traps
- Vacuum pumps and boiler feed units
- Variable frequency drives (VFDs) – hot water circulation pumps
- Premium efficiency motors

The incentive level was set as a function of the incremental measure and labor costs. As noted above, the incentive level was set aggressively to account for the prevailing wage rates and also what it would take to drive and stimulate the local contracting market within the grant period. Higher financial incentives were offered for higher efficiency boilers (e.g., condensing hot water boilers). User friendly incentive tables were created for participating parties to reference. A partial list of these tables can be seen in Figure 3.

Figure 3. Incentive Table Sample

Low Pressure Steam Boilers ≤ 15 PSI		
Boiler Input Capacity	Efficiency	Incentive
75 MBH < Input < 300 MBH	82% ≤ AFUE	\$12 / MBH Input
Domestic Hot Water Boilers		
Input Capacity	Input Capacity	Input Capacity
75 MBH < Input < 300 MBH	84% ≤ E _T ≤ 85%	\$6 / MBH Input
75 MBH < Input < 300 MBH	85% < E _T	\$8 / MBH Input
Thermostatic Radiator Valves – TRVs		
Thermostatic Radiator Valves – TRVs		Thermostatic Radiator Valves – TRVs
Steam Thermostatic Radiator Valve (TRV)		\$75 / TRV

An energy savings methodology was developed as a “deemed savings” approach as opposed to a “measured” or “performance based” approach (see “Deemed Savings Methodology” example below for details). The deemed savings approach was implemented for simplicity due to the high number of retrofits – 243 projects in less than two years. Performance based savings were calculated on a fixed number of properties for case studies and to compare and verify the deemed savings methodology. These select properties were also benchmarked through the EPA’s Energy Star Portfolio Manager where the natural gas usage could be analyzed both before and after the installation of the EEMs.

The program was marketed to the local boiler/mechanical contractors, equipment manufacturer representatives, and to local apartment and property management associations. Within a short period of time, the program became contractor-driven, allowing the contractor to use the program as a tool to generate business. Word spread rapidly among the apartment and property management associations that there was a no-strings program offering generous incentives for heating systems upgrades.

An application process was created requiring a preliminary heating systems audit and pre-installation inspection to verify baseline (existing) equipment, identify potential energy saving options, and confirm building eligibility. Contractors were required to attend training on the Program’s policies and procedures and prevailing wage requirements. Upon approval of an application, utility data was collected from the property owner which would later be used in the energy calculations. Contractors were authorized to commence work, and upon completion, a post-installation inspection was conducted to verify the installation of the incentivized EEMs.

An example of a steam boiler replacement project can be seen in Figures 4 and 5. In addition to significantly reducing the BTU/Hr input capacity of the new steam boiler, observe the physical size differences between the old boiler on the left and the new boiler on the right. The new boiler is approximately 1/3 the size of the old boiler. The old boiler is also insulated with asbestos.

Figure 4.
Existing low-pressure steam boiler (left)
New low-pressure steam boiler (Right)



Figure 5.
New low-pressure steam boiler (close up)
New hot water heater in corner



An example of a water heater replacement project can be seen in Figures 6 and 7. Note that the new high efficiency boilers have AL294C stainless steel stacks while the old boilers used standard galvanized sheet metal stacks.

Figure 6.
Existing Water Heaters



Figure 7.
New High Efficiency Water Heaters



An example of a one-pipe low-pressure steam Thermostatic Radiator Valve (TRV) installation can be seen in Figures 8 and 9.

Figure 8.
One-pipe low-pressure steam
Thermostatic Radiator Valve (TRV)



Figure 9.
Close up photo of TRV with air vent



Whole System Approach

The opportunity to implement a “whole system approach” was taken to improve not just the source of heat – such as the boiler – but the entire distribution system. Such considerations were taken for the following systems:

Low-pressure steam space heating “whole system approach” to “Greening Steam:”

- Replace the low-pressure steam boiler
- Verify the proper size (input capacity) of the boiler and resize
- Split the domestic hot water system from the space heating boiler if needed
- Insulate steam and condensate pipes
- Lower the operating pressure of the boiler to 2 psig or as needed
- Test and replace steam traps
- Verify the operability of thermostats and time-clocks and replace or install
- Install outdoor-reset controls to prevent boilers from operating if the outdoor temperature exceeds the set point temperature
- Install TRVs on radiators to provide more control and eliminate overheating of buildings and the practice of “opening windows” to control room temperature
- Replace air vents on radiators and steam/condensate distribution piping as needed to enhance the even distribution of steam
- Train onsite maintenance personnel and tenants on energy conservation and new EEMs

Heating hot water space heating “whole system approach:”

- Replace the heating hot water boiler with an 84% copper finned tube, fan-assisted, Low NOx boiler to meet the newly adopted BAAQMD air quality regulations or if the location and application (e.g., radiant floor heating which benefits from low (100-°F)

hot water supply temperatures), were feasible, install ultra high efficiency $\geq 90\%$ condensing boilers

- Verify the proper size (input capacity) of the boiler and resize if needed
- Split the domestic hot water system from the space heating boiler if needed
- Upgrade a gravity flow hot water system with a forced circulation hot water pump
- Insulate hot water supply and return pipes
- Verify the operability of thermostats and time clocks and replace or install as needed
- Install outdoor reset controls to prevent boilers from operating if the outdoor temperature exceeds the set point temperature
- Install TRVs on the radiators to provide more control and eliminate overheating of buildings and the practice of “opening windows” to control room temperature
- Replace high point air vents as needed to even the distribution of hydronic heating water
- Train onsite maintenance personnel and tenants on energy conservation and new EEMs

Domestic hot water heating “whole system approach:”

- Split the domestic hot water system from the space heating boiler if needed
- Replace the domestic hot water boiler with an 85% efficient copper finned tube fan assisted Low NO_x boiler to meet the newly adopted BAAQMD air quality regulations or if the location (e.g., means to run new condensate compatible vent) is feasible, install ultra high efficiency $\geq 90\%$ condensing boilers
- Verify the proper size (input capacity) of the boiler and resize if needed
- Insulate hot water pipes and recirculation pipes as needed
- Install data tracking boiler controls to lower set-point temperatures during low peak demands (e.g., in the late evening when demand is low)
- Install temperature limit switches on recirculation pumps to mitigate intermittent heat loss effects
- Train onsite maintenance personnel and tenants on energy conservation (e.g., lowering set point temperatures, conservation of hot water use)

Deemed Savings Methodology to Calculating Natural Gas Savings

A deemed energy savings methodology was developed rather than a measured or performance based savings approach due to the high number of retrofits anticipated and limited staff time to verify performance based projects.

For reporting purposes, energy efficiency savings equations were developed for each EEM. At this time, not all of the projects have been completed and therefore their projected savings and associated metrics have not been reported to date. The most current reportable energy savings and program metrics can be seen in Table 1.

As an example, the equation used to calculate the energy savings for a domestic hot water boiler replacement is the following:

$$Energy_{savings} = (UEC \times NoD) \times \left(1 - \frac{boiler_efficiency_B}{boiler_efficiency_M} \right)$$

Energy Savings Example:

Calculate the projected deemed annual Energy Savings (Therms/year) to replace a 75% efficient (combustion analyzer field verified) central system domestic hot water boiler with a 85% efficient copper finned tube domestic hot water boiler in a 55 unit multifamily building. Per the 2009 California Residential Appliance Saturation Study (RASS), the Unit Energy Consumption (UEC) for water heating is 183 therms per unit dwelling (Kema, 2010).

Given,

$$Baseline_Boiler_Efficiency = boiler_efficiency_B = 75\%$$

$$Measure_Boiler_Efficiency = boiler_efficiency_M = 85\%$$

$$Number_of_Multifamily_Dwelling_Units = NoD = 55_dwelling_units$$

$$UEC = 183_therms/dwelling_unit/year$$

Then,

$$Energy_{savings} = (UEC \times NoD) \times \left(1 - \frac{boiler_efficiency_B}{boiler_efficiency_M} \right)$$

$$Energy_{savings} = (183_therms/dwelling_unit/year \times 55_dwelling_units) \times \left(1 - \frac{0.75}{0.85} \right)$$

Therefore,

$$Energy_{savings} = 1,184_therms/year$$

Table 1. Program Metrics

Program Metrics (totals)	Totals to Date
Number of Projects	243
Project Costs (Labor, Material, Equipment, etc.)	\$5,533,195
Property Owner Costs (Project Cost less Incentive)	\$3,910,903
Incentives (provided by program)	\$1,625,052
Average % of Total Project Cost Incentivized	29%
Prevailing Wage Labor Hours	15,072
Number of Apartment Units	8,142
Building Space (SQFT)	6,578,769
Natural Gas Reductions (Therms)	238,270
Average Incentive Dollars per Therm Saved	\$6.80
Green House Emissions Reduced (CO2e)	1,264
Space Heating Low Pressure Steam Boilers Installed	72
Space Heating Hot Water Boilers Installed	28

Domestic Hot Water Boilers Installed	81
Thermostats Installed	19
Time Clocks Installed	42
Thermostatic Radiator Valves (TRV's) Installed	1,482
Steam Traps Installed	11
Air Vents Installed	1,379
Pipe Insulation (Feet) Installed	12,158

Conclusion

San Francisco's Department of the Environment's ARRA funded Boiler Program was extremely successful. Over 240 multifamily building heating systems were retrofitted to include over 180 boilers replaced with higher efficiency code compliant boilers among many other energy efficiency measures. Contractors saved and created well-paying skilled labor jobs reporting over 14,000 prevailing wage hours, outdated and inefficient heating systems were upgraded, and natural gas and green house gas emissions will be reduced for many years to come.

When developing an incentive-based program of this nature, many factors such as predicting program participation, EEM performance, and funding source rules (e.g., labor compliancy requirements, IOU and state regulations) can influence a program's structure, incentive levels, objectives, and success. Looking into the future beyond ARRA stimulus funding, these boilers represent a significant opportunity for energy efficiency reduction and should be captured in ratepayer funded programs under the jurisdiction of the California Public Utilities Commission. While current energy efficiency regulations which set incentive levels are reasonable, these ancient boilers need an amnesty program. Therefore, the ratepayer programs need to include enough incentives to convince building owners to replace their ancient boilers.

References

- U.S. Census Bureau. 2010. <http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml>
- [CCSF] City and County of San Francisco. 2010. *San Francisco Energy Watch Multifamily and Commercial Plus Programs. Policies and Procedures Manual. Appendix B. 2010-2012 Program*
- [CCSF] City and County of San Francisco. 2007. *Housing Code. Chapter 7. Section 701*
- State of California. 2012. *California Code of Regulations. Title 8 – Industrial Regulations. Chapter 8. Subchapter 3. Article 2. (b)*. <http://www.oal.ca.gov>
- Kema. 2010. *2009 California Residential Appliance Saturation Study (RASS) –Volume 2. Table 2-21* . <http://www.energy.ca.gov/appliances/rass/>