Boiler Plant Upgrades

OVERVIEW

Boilers provide hot water for space and domestic hot water heating applications. A substantial portion of the total energy consumption in most residential, commercial and institutional buildings is used for hot water heating, as much as 40%. Improving boiler efficiency results in a reduction of energy consumption and operational cost, while mitigating environmental impacts.

EFFICIENCY DEFINITIONS

There are primarily two ways to define boiler efficiency:

1. **Combustion efficiency** is the efficiency of the burner to combust the fuel. It is calculated as the ratio of energy output (the energy input minus the stack losses) to the energy input.

2. **Thermal efficiency,** also referred as the overall efficiency, is the efficiency of the burner and the heat exchanger to transfer heat to the useful side of the heat exchanger. It is calculated as the gross energy output divided by energy input. Thermal efficiency is lower than combustion efficiency by the percentage of heat loss from the outside surface of the boiler (via radiation loss or jacket loss) and by off-cycle energy losses (applications that boiler cycles on and off).

3. **Seasonal Efficiency** is the actual operating efficiency that the boiler will achieve during the heating season at various loads. Because most heating boilers operate at part load, the part load efficiency, including the heat losses when the boiler is off, has a great effect on the seasonal efficiency. The difference in seasonal efficiency between a boiler with an on/off firing rate and one with modulating firing rate can be appreciable if the airflow through the boiler is modulated along with the fuel input (source ASHRAE Handbook 2012).

BOILER UPGRADES

There are two options for replacing standard efficiency boilers: condensing and near-condensing boilers. Near-condensing boilers have steady state combustion efficiencies of 85 to 88 percent, whereas modern condensing boilers have steady state combustion efficiencies between 89 and 98 percent[1]. New conventional non-condensing models have energy efficiencies of only 70 to 85 percent. Many boilers over 20 years old typically operate at only 60 to 70 percent efficiency, making them good candidates for upgrading or replacement.

High-efficiency condensing boilers feature additional advanced heat exchanger designs and materials that extract more heat from the flue gases before they are exhausted. The temperature of the flue gases is reduced to the point where the water vapour produced during combustion condenses back into liquid form, releasing the latent heat, which improves energy efficiency. When water condenses in the flue gas it is an indication that more heat is being absorbed, which is why it is called a condensing boiler. Due to the corrosive operating conditions, condensing boilers must be built with more expensive materials, which increases the initial cost.

Condensing boilers operate at their peak efficiency when the return water temperatures are below 55 °C (131 °F). When low return water temperatures are not feasible, a near-condensing boiler may be more practical and cost effective.

Radiant in floor heating systems are prime applications for condensing boilers because they typically have a large temperature drop and low return water temperatures. Alternatively, heating coils can be designed to allow for a greater temperature differential, which will reduce the return water temperature. Although this is often not feasible for a retrofit, new construction and major equipment replacement/upgrades provide opportunities for coil designs suitable for condensing.

[1] Based on data obtained from Fortis BC Efficient Boiler Program - Eligible Boiler List and their efficiencies

http://www.fortisbc.com/NaturalGas/BuildingProfessionsTrades/IncentivePrograms/Pages/Efficient-Boiler-Program-Eligible-Boiler-List.aspx

BURNER CONTROL

There are three main ways to control the flame in the combustion chamber of a boiler; on-off control, staged control, and modulating control.

On-off control is the simplest method, with the fuel flow either fully on or off; however, when the load on the boiler is low, on-off control will cause the boiler to cycle excessively. This is not only inefficient, but also increases wear and tear on the boiler. Staged control allows the burner to operate at several different stages of firing; off, medium, high for example. This offers improved control over the simple on-off strategy. With modulating burners, the firing rate is matched to the required load. The minimum firing rate with modulating control is defined by the boiler turn-down ratio. Modulated firing, the most efficient burner control, results in fewer heating cycles and lower standby losses than on-off firing, and improved load matching over staged control. For some boilers with on/off control, it is possible to retrofit just the burner to modulating control.

INCENTIVES IN BC

FortisBC's Efficient Boiler Program (EBP) spearheaded the boiler upgrade initiative in British Columbia by providing incentives for upgrading to high or mid efficiency boilers (condensing or near-condensing) for new construction and replacement projects. A 2011 study, conducted by Prism Engineering, assessed 135 sites, including multi-unit residential buildings (MURBs), office buildings, schools and other types of buildings which participated in the EBP. The study revealed that installing a high-efficiency boiler for space and water heating achieved an average energy savings of 16 percent. Schools achieved the highest average savings of 20% which is partly due to the fact that boiler controls improvements were implemented along with the boiler replacement. Sites with high efficiency condensing boilers achieved savings of 18%.

CASE STUDY

In September 2008, Vanway Elementary School located at Prince George (School District 57) replaced their heating system with two near- condensing boilers manufactured by Thermal Solutions (Model EVA1500M) with an input rating of 1500 MBH each and steady state efficiency of 85.8%.

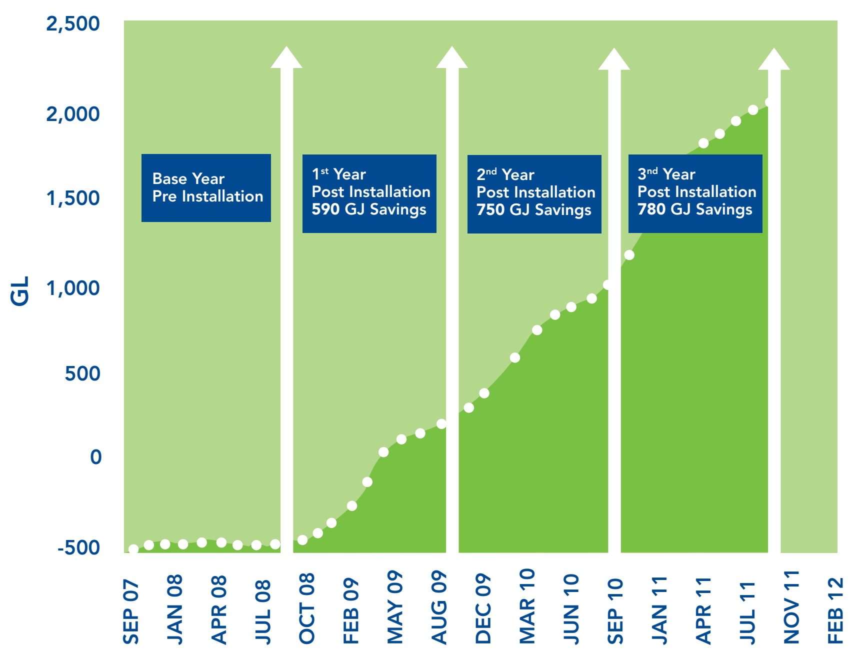
A monitoring and verification analysis indicates gas savings of 36% over a three year period as shown in the table below. Vanway Elementary School consumed 1,960 GJ from September 2007 to August 2008, which was selected as the base year for calculating the achieved savings. All savings calculations are adjusted for year to year weather variations.

	From	To	Savings (GJ)	% Savings
First Year	Sept 2008	Aug 2009	590	30%
Second Year	Sept 2009	Aug 2010	750	38%
Third Year	Sept 2010	Aug 2011	780	40%
	Total 3 Years Savings		2120	

The retrofit cost was estimated at approximately $120,000[2]. Fortis BC contributed an incentive of approximately $15,000, which lowered the retrofit cost to a net amount of $105,000. Based on an average gas rate of $10/GJ, the cost saving in the third year was approximately $7,800 per year.

Vanway Elementary

Cumulative Summary - Gas Savings



[2] The total project cost was approximately $600,000. However, that included multiple retrofits and new other equipment installations. Since an accurate breakdown of the boiler installation could not be obtained from the contractors, boilers cost (labour and material) was estimated based on similar projects implemented in other sites.

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