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Review of Building Performance Improvements through the Addition of Hydronic Additives to Boiler Plant Loops

Ashish Dev, Adrian Pettyfer, Will Wilson and Dale Edginton

ABSTRACT

Coquitlam School District (SD43) conducted a pilot study that was run at 4 elementary schools between September 2020 and March 2021 to review the performance of Endotherm® on its heating plants. Endotherm® is a surfactant additive for hydronic HVAC boiler systems which claims to improve heat transfer and lowers energy consumption. The sites were selected out of a sample of 45 schools based on their correlation between consumption and heating degree days (HDD) and the tightness of the heating loop. This baseline and subsequent trendline were used to predict consumption in the post-installation comparative period taking guidance from Option C of the International Performance Measurement and Verification Protocol (IPMVP). The impact of COVID-19 on sites was measured by comparing these sites with other sites with no reported technological or mechanical changes. Over the 6- to 7-month study period, the four Endotherm® pilot sites reduced consumption by 11.35%, while compared control sites saw an increase of 8.05%. During the study period, the sample sites saved $3003 in reduced energy consumption and reduced emissions by 18,700 kg of CO_2e. Based on this performance, the simple payback is expected to be within two years when incorporating a rebate from the local natural gas utility, FortisBC Inc. This pilot study will be used by the school district for further installation approval for other sites within their portfolio.

INTRODUCTION

Organizations and governments throughout the world are focusing on ideas and technologies that will reduce greenhouse gas (GHG) emissions due to climate change but not affect our ability to meet our global energy requirements. According to the Center for Climate and Energy Solutions (Leung 2018), commercial and residential buildings account for 29% of all North American greenhouse gas emissions. Space heating represents the largest end-use in buildings consuming more than 7 trillion Joules of energy. Optimizing the efficiency of boiler plants will continue to play a large part in achieving reduction targets.

Hydronic boiler systems, which make up most commercial heating plants, typically require chemical additives including corrosion inhibitors to reduce corrosion and glycol to prevent freezing. Advancements in hydronic additive technology have resulted in solutions that improve heat transfer, reducing energy consumption and GHG emissions.

Pace Solutions Corp introduced Endotherm® as an energy-saving additive for hydronic boiler systems. Water is used in all hydronic boiler systems as a delivery method to move heat from the boiler throughout the building. Endotherm® reduces the boiler water's surface tension increasing the contact surface area available for heat transfer. The improvement in heat transfer results in a proven 10 to 15% reduction in energy consumption and emissions.

Endotherm® is a thermally stable non-ionic surfactant that can reduce the surface tension of water by over 60% at only a 1% dilution. With a lower surface tension, the wetted perimeter or thermal contact area of system water is improved, providing increased turbulence through the boundary layer at the heat transfer surface. This effect is shown in Figures 1 and 2.

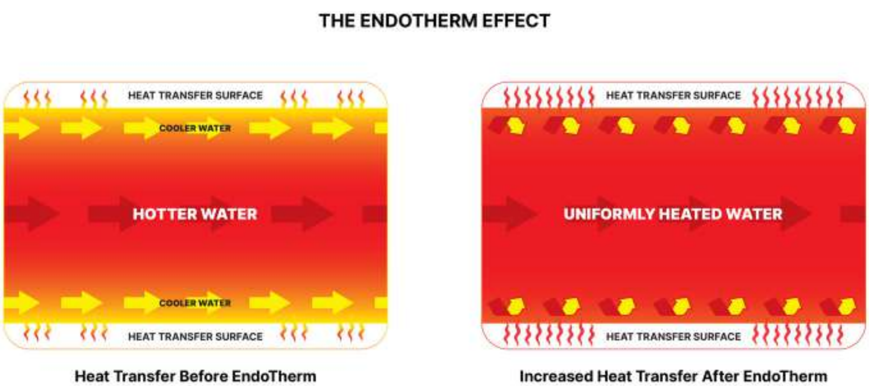

Figure 1. The Endotherm Effect

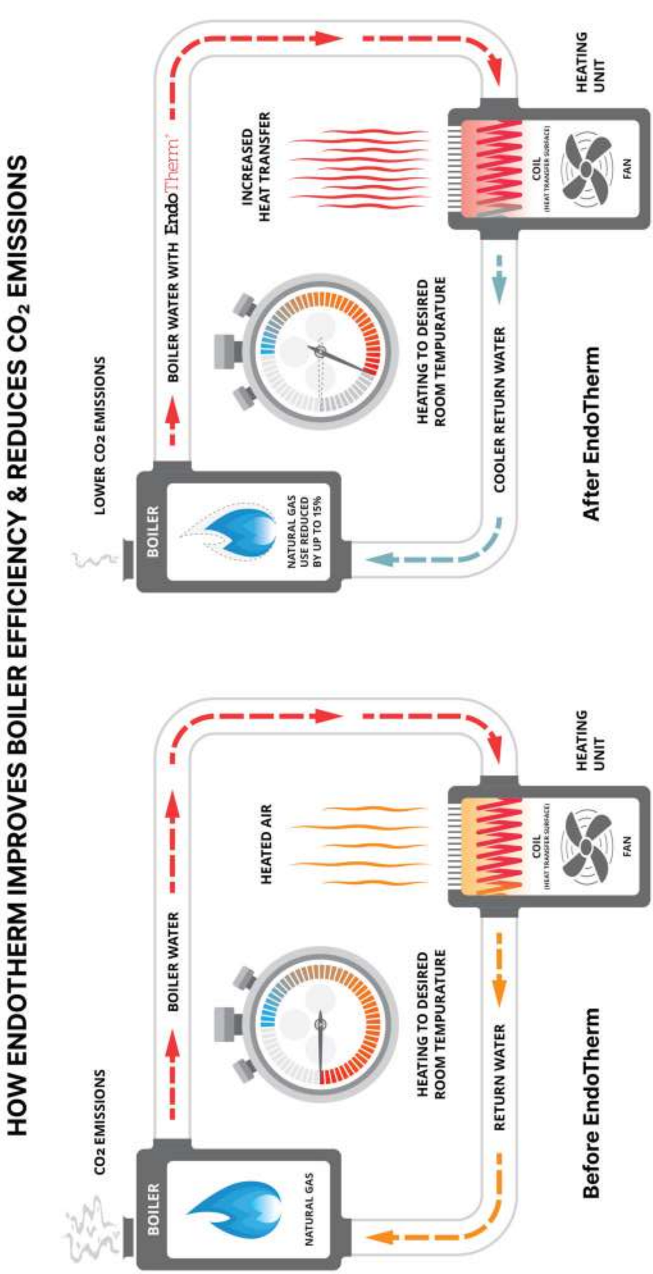

Figure 2. How Endotherm Improves Boiler Efficiency and Reduces CO2 Emissions

This results in an improvement in heat transfer efficiency and ΔTs (difference between flow and return temperatures). Ultimately installing Endotherm® allows buildings to get to thermostatic set points faster, reducing run times while also allowing a reduction in flue gas losses in condensing boiler systems.

Since 2018, FortisBC, an electricity and natural gas distribution utility in the Canadian province of British Columbia had conducted a 25 building, multi-client peer-reviewed study of Endotherm® as part of their Innovation Demonstration Program which resulted in a rebate offering to FortisBC customers in July 2020. FortisBC offers a $200/gallon point-of-sale rebate for Endotherm®.

Per the British Columbia's Climate Change Accountability Act, all PSOs (Public Sector Organization) are required to reduce GHG emissions by 40% (below 2007 levels) by 2030, 60% by 2040, and 80% by 2050. Close to 95% of BC's electricity is generated by renewables and thus reducing natural gas consumption is essential for PSOs to achieve this goal.

Coquitlam School District is one of the largest school districts in British Columbia, managing 87 schools. The district is actively looking for opportunities to reduce the GHG emissions at their schools which primarily come from space heating boilers. During the 2020 AEE West Conference, Pace Solutions Corp presented information on Endotherm®. Intending to verify the energy efficiency claims of Endotherm®, Coquitlam School District implemented a product pilot at four elementary schools.

METHODOLOGY

To review the performance of this additive, a study was conducted by Coquitlam School District with support from Pace Solutions Corp. The study was divided into 3 parts: Site Selection, Installation, and Measurement and Verification (M&V) review.

Site Selection

A baseline analysis was conducted on 45 schools operated by the school district using historical monthly billing data from FortisBC. The sites with the strongest historical correlation between gas consumption and heating degree days (HDD) were selected as the best candidates to verify Endotherm® energy savings. Schools were removed from the study if they had recent or planned retrofits during the pilot period or had significant leakage from the hydronic systems. Four ideal candidate buildings were identified and shown in Table 1. To provide a representative sample of the different types of systems in the school district, two condensing boiler sites, and two atmospheric boilers sites were selected.

Table 1. School-wise Energy Baseload Calculations

Energy Baseload Calculations					
Building	**Annual GJ**	**Baseload**	**Boiler GJ**	**Tonnes CO_{2e}**	**Annual Gas Cost**
School 1	729	90%	656	43.90	$5,576
School 2	1420	80%	1136	85.51	$9,656
School 3	1393	90%	1254	83.89	$10,656
School 4	1384	90%	1246	83.34	$10,588
Total	4926	90%	4291	296.64	$36,476

Implementation

Endotherm® is dosed at 1% of the total system volume. It can be injected or added to the hydronic system through a pot-feeder similar to adding glycol or inhibitors.

Endotherm® was added to the boiler water at each of the four schools in August 2020. Installation took approximately one hour per site and required no downtime or setpoint changes. No other changes were made to the system to isolate performance to Endotherm®. A summary of the treatment costs is shown in Table 2.

Table 2. Endotherm® Project Cost

Project Cost			
Building	**Treatment**	**Rebate**	**Net Cost**
School 1	$2,728	$800	$1,928
School 2	$2,046	$600	$1,446
School 3	$2,046	$600	$1,446
School 4	$2,728	$800	$1,928
Total	**$9,548**	**$2,800**	**$6,748**

Measurement and Verification Review

The measurement and verification (M&V) study for this project took guidance from the IPMVP Option C. A historical baseline for consumption is measured at all sites by comparing gas usage to HDD. Pilot sites that had a good correlation between HDD and gas usage were selected because any change in consumption would be easy to identify.

Natural gas consumption was weather normalized for outside temperature variances using HDD (18.5°C) from Pitt Meadows Coastal Station.

A regression line was calculated using the historical consumption. A trendline was calculated which can be used to predict consumption (y) based on a known HDD value for that month. This can be compared with the calculated consumption for any given month to determine a change in demand caused by the Endotherm®.

OBSERVATION

The basic objective of this study was to identify low-cost opportunities to improve building performance and reduce energy consumption instead of undertaking large capital cost replacement projects. The energy consumption for the last 2 years was reviewed along with a summary as presented in Table 3.

Table 3. 2019-2020 Natural Gas Energy Consumption, Cost and Performance Summary

School	Floor Area (m^2)	Natural Gas Energy 2019 (GJ)	Natural Gas Energy 2020 (GJ)	Natural Gas EUI 2019 ($ekWh/m^2$)	Natural Gas EUI 2020 ($ekWh/m^2$)	Natural Gas Energy Reduction GJ (2020)	Natural Gas Cost 2019 ($)	Natural Gas Cost, 2020 ($)
School 1	2960	716.1	682	67	64	34	7,000	6,469
School 2	2960	1349	1266	127	119	83	12,758	11,713
School 3	3250	1409	1355	120	116	54	13,536	12,607
School 4	3412	1408	1347	115	110	61	1,3388	12,431

It is noted that the COVID-19 pandemic has had a significant impact on traditional usage and occupancy and thus energy demand on-site. Many schools closed in March 2020 which can be reflected in a reduction of consumption in some (but not all) sites between March and May 2020. With schools (and buildings in general) re-opening in September 2020, ASHRAE released guidance to:

1. Increase outdoor air ventilation.
2. Disable demand control ventilation.
3. Open minimum outdoor air dampers as much as 100% to maximize fresh air flow and eliminate air recirculation.
4. Keep systems running longer hours (24/7 if possible) to help the circulation of air.

This has caused a well-documented general increase in consumption across buildings in North America.

For this reason, it was decided to run the same analysis for 2 similar elementary schools that did not have Endotherm® installed to act as a Control to compare the Endotherm® study sites against. The study was run for 6-7 months between September 2020 and February/March 2021.

For each site, several baselines were considered for analysis. This included natural gas consumption from March 2018. The Fall 2019 to Feb 2020 heating season pre-COVID and consumption between March 2020 and installation. Figure 1 shows that the efficiency of the school had improved from Summer 2019 and thus a shorter baseline would be the one considered for the pilot study.

The chosen baseline is then compared with the same data after Endotherm® was installed. A predicted consumption is calculated using the trendline (in the form of y = mc + c) and compared with the recorded baseline for the period.

The cumulative sum (CUSUM) of each month between September 2020 and February 2021 was used to determine the energy efficiency improvement of each system.

Scatterplot outliers identified at these sites can be attributed to estimated billing from stakeholders rather than documented data. With movement restricted, so is the ability to collect actual meter readings and thus some of the values are estimated (on trend with the baseline) with larger savings reflecting 2- to 3-month windows rather than individually monthly savings. However, the saving over the 6- to 7-month period is reflective of actual meter readings and the correct period for normalization using HDD. A summary of savings and comparison to control schools is shown in Table 4.

Over the study period, the four Endotherm® schools showed a significant reduction in natural gas consumption ranging from 4.37% to 16.46%. The combined average gas savings is 11.35% which falls within Endotherm's® expected savings of 10-15% as previously tested in other

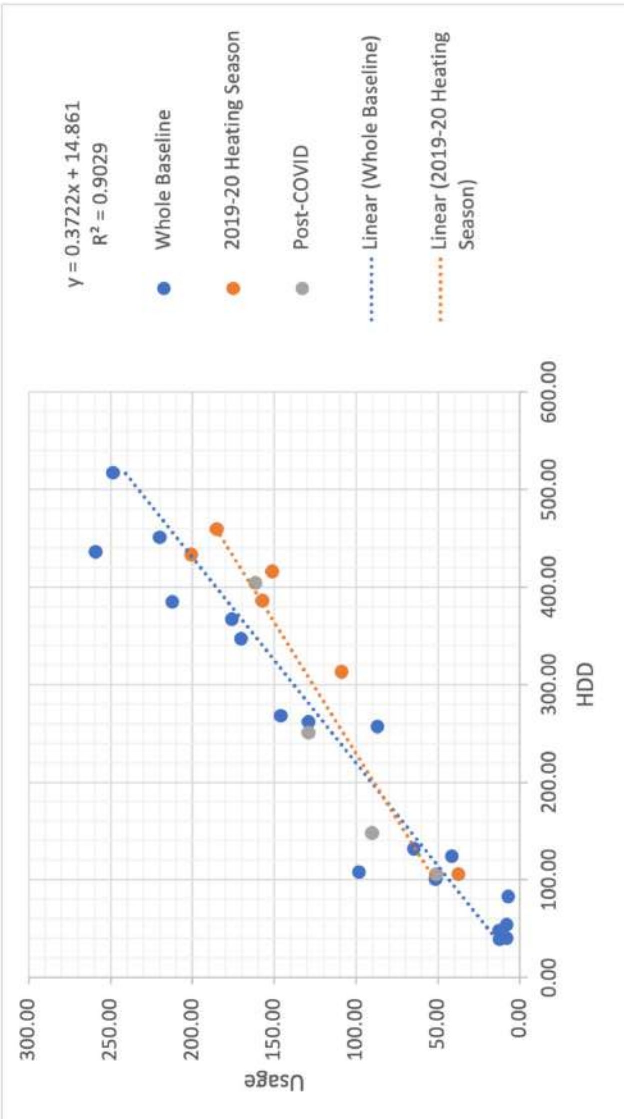

Figure 3. Baseline Analysis of School 1 (Sample)

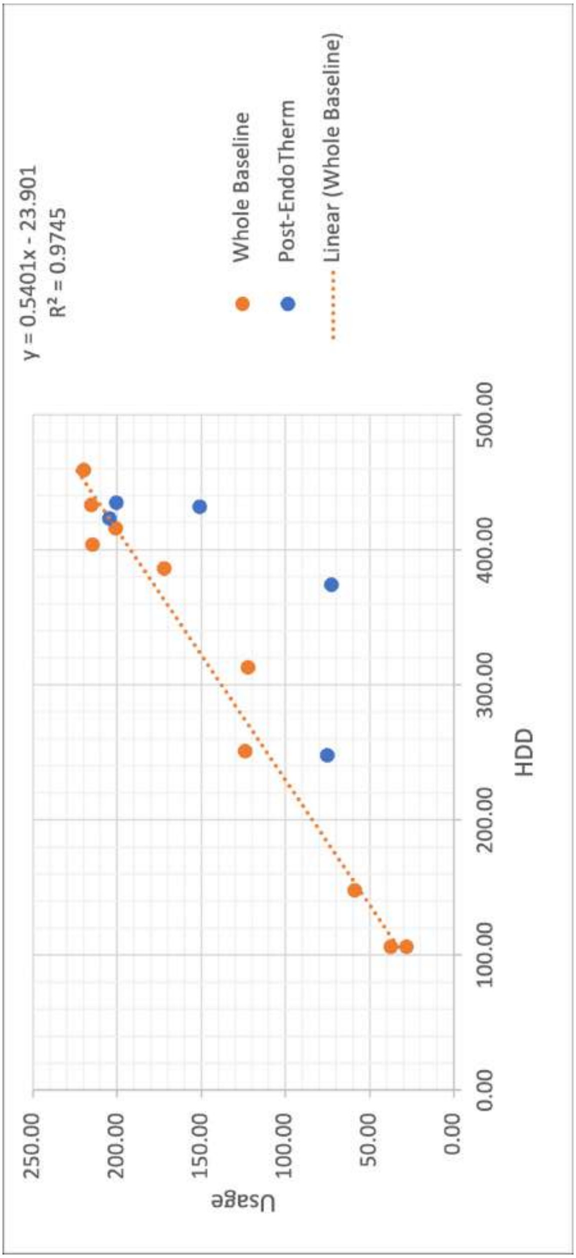

Figure 4. Post-Endotherm® analysis at School 2 (Sample)

Table 4. Savings Comparative between Endotherm® and Control Schools

	Site Name	Pilot Length	Saving (%)
Endotherm® Sites	**School 1**	6 Months	14.27
	School 2	6 Months	4.37
	School 3	6 Months	16.46
	School 4	7 Months	10.31
	AVERAGE		**11.35**
Control Sites (No Endotherm®)	**School 5**	6 Months	2.53
	School 6	6 Months	-18.63
	Average		**-8.05**

locations in British Columbia.

At a unit price of $8 per gigajoule of natural gas, the study period provided a gas savings of $3,003, providing the district a simple payback in the first two years despite the increase in consumption caused by the pandemic. Projected savings over the next ten years is estimated at $23,282, with a 500% return on their investment. The reduction in natural gas in turn creates a reduction in carbon emissions. The reduction of 375.38 GJ offsets 18,760kg of CO_2e which is the equivalent to the annual emissions from four passenger vehicles.

The control schools, which did not receive Endotherm® experienced an 8.05% increase in natural consumption over the same 6-month pilot period. An overview of all schools in the district revealed a 7.8% increase in natural gas consumption in 2020 compared to prorated baseline.

Table 5. Summary of School-wise Energy Savings and GHG Savings

Site Name	Saving (%)	Saving ($8/GJ)	Saving (GJ)	Carbon Saving (kg CO_2)
School 1	14.27	634.19	79.27	3,963.68
School 2	4.37	289.57	36.20	1,809.84
School 3	16.46	1,224.34	153.04	7,652.10
School 4	10.31	854.99	106.87	5,343.69
AVERAGE	**11.35**			
TOTAL		**3,003.08**	**375.38**	**18,769.30**

CONCLUSION

Endotherm® was dosed into four buildings with a combined cost of $6,748 including installation. A pilot study methodology was constructed taking guidance from IPMVP (Option C) comparing a historical baseline (normalized with HDD) with post-install consumption data.

Over the 6- to 7-month pilot study period from September 2020 to March 2021, the 4 sites achieved an average 11.35% reduction in natural gas consumption, while the two comparative control buildings had an average natural gas consumption increase of 8.05%. This is also supported by a district-wide analysis showing an overall natural gas consumption increase of 7.8% when compared to the prorated baseline.

The pilot study project saved $3,003 in reduced utility costs providing the district with a simple payback within the first two years. The direct reduction in natural gas can also be seen as an offset of 18.7 metric tonnes of carbon dioxide equivalent.

The Endotherm® product was easy to install with no system downtime and no mechanical issues reported within the first 11 months of operation. The additive has an expected lifespan of over ten years, providing a projected return on investment of approximately 500%. Coquitlam School District will continue to install Endotherm® into more of its schools and gauge performance. In 2020, the school district used 128,756 GJ of natural gas. If Endotherm® is introduced on a District-wide scale, an 11.35% district-wide savings would account for 14,613 GJ which is an equivalent saving of $116,910 per annum.

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AUTHOR BIOGRAPHIES

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Dale Edginton is the operations manager with Endo Enterprises (UK) Ltd the global manufacturer and IP owner of Endotherm®. Having supported the launch of the Endotherm® product as UK sales manager between 2014-2017, Dale moved to British Columbia to help launch North American Operations. Dale has run over 400 M&V case studies on Endotherm® across 4 continents. Dale Edginton can be reached via email at dale.edginton@endoenterprises.com.

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The International Journal of Energy Management is an official bi-monthly publication for members of the Association of Energy Engineers. The journal publishes original articles and papers detailing the latest engineering or analytical approaches to energy management and energy efficiency.

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