UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Measurement Investigation for Behaviour Change Campaigning within UBC Residences

Jacob George

University of British Columbia

APPP 506

Themes: Climate, Energy, Water

December 2018

Measurement Investigation for Behavioural Change Campaigning within UBC residences

Jacob George

University of British Columbia

December 2018

Table of Contents

1. Executive Summary

This project intends to investigate the impact of the Fall 2018 Shorter Showers campaign at the University of British Columbia (UBC) student residences. The main purpose of the project was to analyse the energy, water, and greenhouse gas (GHG) savings associated with the behaviour change campaign. Consequently, the project sought to determine the best practices for a measurement program to support specific energy and water savings campaigns within UBC student residences, and to provide recommendations for measurement and verification (M&V) for future campaigns.

The targeted residence for this project was Building 10 at Totem Park- Cesnam (c̓əsnaʔəm) House. Based on the initial analysis, there were no quantifiable savings as a result of this campaign. An increase in hot water energy consumption was identified despite weather normalizing to eliminate any effect of the hot water used for building heating.

Keywords: Measurement and verification (M&V), Community-based social marketing (CBSM), Data analysis, Shorter shower campaign.

2. Introduction

According to the Key World Energy Statistics (2017) published by International Energy Agency (IEA), the energy consumption of the residential sector in 2014 was 20% of the total global energy consumption. In private households, about 70% of energy is used for heating, approximately 15% for warm water, and about 12% for household appliances and consumer electronics such as televisions, computers, refrigerators, and freezers (International Energy Agency, 2003).

In 2010, the IEA estimated that by 2020, 34% of the global reduction in carbon emissions in a 450 scenario (limiting the long-term concentration of greenhouse gases in the atmosphere to 450 ppm CO2-eq) would come from direct end-use energy efficiency methods. Historically, governments and other organizations have been dependent on policy and energy-efficient technology to reduce energy consumptions. For example, minimum-efficiency standards for residential appliances and lighting have been utilized, however, these standards have been criticized as being inefficient, due to uniform standards for heterogeneous consumers and the "rebound effect"- the phenomenon of reduction in energy savings from an energy efficiency improvement or technology due to changes in behavioural response or similar attributes. While energy efficiency is considered a key strategy for climate change mitigation, it also reduces the need for investment in new energy production infrastructure and equipment.

As energy production and consumption continue to increase, it has become vital to consider the role of consumer behaviour. Energy savings from the change in occupant behaviour are often neglected although energy behaviours are considered to be as significant as technological solutions. (Lopes, Antunes, Martins, 2012).

3. Background

This project intended to investigate the impact of the Fall 2018 Shorter Showers campaign at the University of British Columbia (UBC) student residences. The main purpose of the project was to analyse the energy, water, and greenhouse gas (GHG) savings associated with the behaviour change campaign. Consequently, the project sought to identify best practices for a measurement program to support specific energy and water savings campaigns within UBC student residences, and to provide recommendations for measurement and verification (M&V) in future campaigns.

The Sustainability and Engineering department, in collaboration with the Student Housing and Hospitality Services, organized the Shorter Showers campaign to support the ambitious UBC greenhouse gas (GHG) emissions reduction target. This campaign forms part of a larger behavioural change program aimed at meeting UBC's Climate Action Plan (CAP). This aggressive plan sets to reduce GHG emissions by 67% for 2020 and net zero emissions by 2050 based on a 2007 baseline year. Previous campaigns include Sweater Day, Shorter Showers, Bike to Work, Turn off the Lights and many more. A comprehensive study by Minnesota Department of Commerce (2015) shows community-based social marketing (CBSM) campaigns have electricity savings ranging between 0.1% to 14%.

The intended energy savings was achieved by raising pledges from students in campus residences to make small behaviour changes- reduce shower times to 5 minutes or less. This behaviour change was disseminated by creating awareness of the environmental impacts of hot showers through resident advisors and student volunteers, booths in the residences, posters around communal areas, digital marketing through social media and door and shower hangers with a shorter showers prompt. The primary targeted population was the first-year students of approximately 6000 students, across five different residence complexes: Totem, Orchard, Vanier, Walter Gage and Ritsumeikan. The student demographic profiles were recorded by online surveys conducted at the time of the pledges. The campaign was incentivized through a competition between the various houses/floors, with the highest proportion of pledges earning a pizza party, as well as the chance for pledge-takers to enter a draw for additional randomized prizes.

4. Literature Review

This section covers the different theories and models describing energy behaviour, as well as the Community-based Social Marketing (CBSM) framework which was utilized for the Shorter Showers campaign. Finally, a brief introduction to Measurement & Verification is provided. According to Lopes, Antunes, Martins (2012), the most comprehensive review of energy behaviour frameworks in the 21st century was conducted by Wilson and Dowlatabadi (2007).

4.1 *Decision theories*

The following models provide useful insight into the relationship between personal behaviours and practices and contextual factors (skills, norms and expectations):

- Social norm theory: This theory aims to understand the effect of interpersonal influences on individuals. In essence, individuals have a strong tendency to conform to group patterns and expectations.
- Value-belief norm theory: This theory states that once a person is aware of the consequences of his actions and feels responsible for causing or preventing the consequences, the environmentally-responsible behaviour is triggered.
- Attitude-Behaviour-External Conditions (ABC) model: According to this model, attitudes lead to behaviour change only if external conditions (such as financial, social or legal) act as an incentive or disincentive.

4.2 Behavioural economics

Neoclassical economics revolves around the idea that human beings consistently make the most rational and logical decisions, which increase satisfaction and maximize resource utility. The glaring trouble with this theory is that human beings are not completely rational creatures, and the imperfections in their decision making (or bounded rationality) has been taken into consideration in the evolution of a new kind of theory - behaviour economics.

- Choice overload: Thaler & Sunstein (2009) suggest that a neoclassical economic approach to behaviour change assumes that individuals make the best choices when given the maximal number of available options and information. However, this has seen to be inaccurate, on account of "choice overload". When presented with masses of information and a multitude of choices, individuals are less likely and less able to thoroughly consider their options, often electing to act in ways that are actually against their best interests.

- Framing and reference dependence: Consumers make different decisions depending on how the choices are framed. The results can vary depending on whether the decision is framed as a choice between gain or loss.
- Heuristic decision-making: Individuals are likely to make the majority of their decisions using heuristics (simple decision rules), which affect the relative discounting rates according to the available options.

4.3 Community-based Social Marketing (CBSM)

Community-based social marketing provides a practical framework by identifying behaviours to change and encouraging new behaviour. “Community-based social marketing is based upon research in the social sciences that demonstrates that behaviour change is often most effectively achieved through initiatives delivered at the community level, which focus on removing barriers to an activity while simultaneously enhancing the activity’s benefits” (McKenzie-Mohr, 2011, p).

Doug McKenzie-Mohr (2011) propose a 5-stage model for community-based social marketing:

1. Selecting which behaviour to target;
2. Identifying the barriers and benefits to the selected behaviour;
3. Developing a strategy that reduces barriers to the behaviour to be promoted, while simultaneously increasing the behaviour’s perceived benefits
4. Piloting the strategy; and
5. Broad-scale implementation and ongoing evaluation once the strategy has been broadly implemented.

A number of intervention tactics are summarized in *Fostering sustainable behavior: An introduction to community-based social marketing* (McKenzie-Mohr, 2011) to create a successful community-based social marketing program to promote environmentally responsible behaviour. Below are some relevant tactics to be considered when designing a community-based social marketing campaign:

- Commitment: Emphasis on public commitment, as people have a strong desire to perceive them selves as consistent. This is particularly true about groups of people who have close ties with each other.
- Prompts: Humans are naturally forgetful. Vivid, self-explanatory prompts placed as near as possible to where the behaviour is to be carried out, serve as a reminder to perform the environmentally-responsible behaviour.
- Norms: Create and publicize social norms, to promote the intended environmentally-responsible behaviour and reinforce it through personal contact.
- Social Diffusion: Develop creative methods to increase the visibility of the environmentally-responsible behaviour, as this increases social diffusion through discussions of the behaviour. Recruit prominent personalities in the community to diffuse the behaviour increases the adoption rates (Rogers, 2003)
- Communication: Develop communication strategies using captivating and credible information, framing the message to target the intended audience, and providing feedback about the effectiveness of the desired behaviour.
- Incentives/Disincentives: Incorporate the use of non-monetary incentives in the campaign and ensure high visibility to draw attention to these. As much as possible, try to reduce the time between the incentive and the environmentally-responsible behaviour.
- Convenience: Identify external barriers and plan to mitigate them where possible.

4.4 Measurement and Verification

In order to realize a reduction in energy and water consumption, the active involvement of consumers is required. This is achieved by monitoring and auditing within the consumption chain, organizing data and observing any trends in the change in consumer behaviour. These trends can be analyzed to encourage cultural and educational changes through governmental and organizational policies. Advanced Metering Infrastructure (AMI) allows for the development of efficient and sustainable energy management solutions through the rational use of resources by the active participation of users (Lima, Navas, 2012).

The International Performance Measurement and Verification Protocol (IPMVP) outlines the best practices to verify results for projects in the energy efficiency sector. Measurement and verification for energy reduction projects is the process of quantifying the difference in consumption against a baseline period. According to the *International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings* (2002), there are four IPMVP options available:

- IPMVP Option A- Partially Measured Retrofit Isolation: Savings are quantified by the partial field measurements of the energy use of the system to which Energy Conservation Methods (ECM) were applied.
- IPMVP Option B- Retrofit Isolation: Savings are quantified by the field measurements of the energy use of the system to which ECMs were applied.
- IPMVP Option C- Whole Facility: Savings are quantified by measuring the energy use of the complete facility over a specific period of time.
- IPMVP Option D- Calibrated Simulation: Savings are determined through simulation of the energy use of the whole facility or components of it.

There are quantifiable and unquantifiable uncertainties in this process. Quantifiable uncertainties are typically measurement, sampling and modelling uncertainties. Unquantifiable uncertainties arise from poor placement of meters, inaccurate estimations in IPMVP Option A or incorrect estimations of interactive effects in IPMVP Option A or Option B (International Performance Measurement & Verification Protocol Committee, 2003).

4.5 Weather Normalization

Weather normalization allows for a similar comparison of energy consumption over multiple time periods with differing weather conditions. It allows for the tracking of energy performance over time, while excluding the impact of varying outside air temperatures. Weather normalized data are calculated by correlating the energy usage with heating degree days (HDD), which allows for a quick understanding of whether the change in energy consumption is the result of operational or weather changes.

The first step is to obtain the daily energy consumption data in kWh and the corresponding HDD data. The next step is to correlate the energy consumption with the HDD data using a regression analysis.

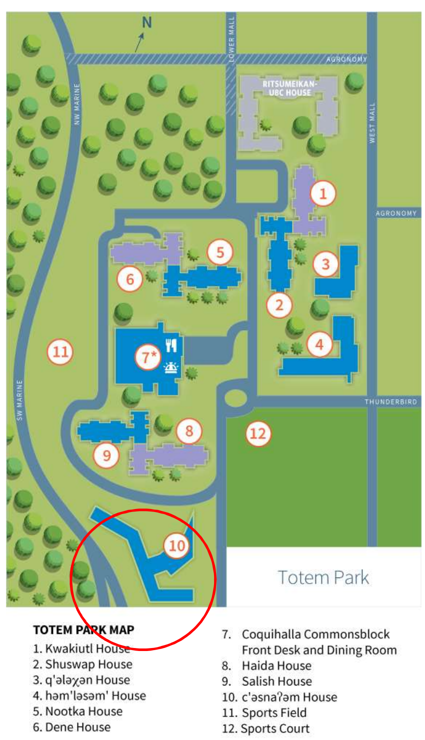
Generally, an R^2 value closer to 1 indicates a better correlation. A value less than 0.7 is a likely indication that the heating control is poor, or the analysis needs improvement.

5. Methodology

The first project objective was to map out the various residence buildings, and the corresponding criteria like heating and ventilation, food and laundry services located in the targeted buildings. This was done through a mixture of information from SkySpark (the building energy and water cloud database system), Building Management Systems (BMS) and interviews with staff. The next step was to identify the corresponding district hot water meters associated with the targeted population from the BMS. The targeted residence for this project was Building 10 at Totem Park- Cesnam (c̓əsnaʔəm) House (Fig. 1). This residence was selected as the end-use of district hot water energy was determined to be mainly only for domestic hot water, and for building heating via a hot water heating coil in the Heat Recovery Ventilation (HRV) unit. Electric baseboards in each bedroom provide the majority of the heating within this residence, while a HRV unit provides the remaining heat. The other residence buildings tended to have hot water heating within each bedroom.

The Cesnam (c̓əsnaʔəm) residence housed approximately 350 students at the time of this campaign. The site has only one laundry room on the main floor, and two dishwashers- one in each coordinator's unit on the main floor.

Figure 1. Totem Park



The BMS screenshot (Fig. 2) shows the district hot water entering the building and passing through the Heat Exchangers (HE). The energy from here is used for two end-uses. Firstly, for domestic hot water (Fig. 3) and secondly for heating via a hot water coil in the Heat Recovery Ventilator. This process can be observed in Figure 4 at 14:15 with an outdoor temperature of 11.5°C.

Figure 2. BMS- District hot water

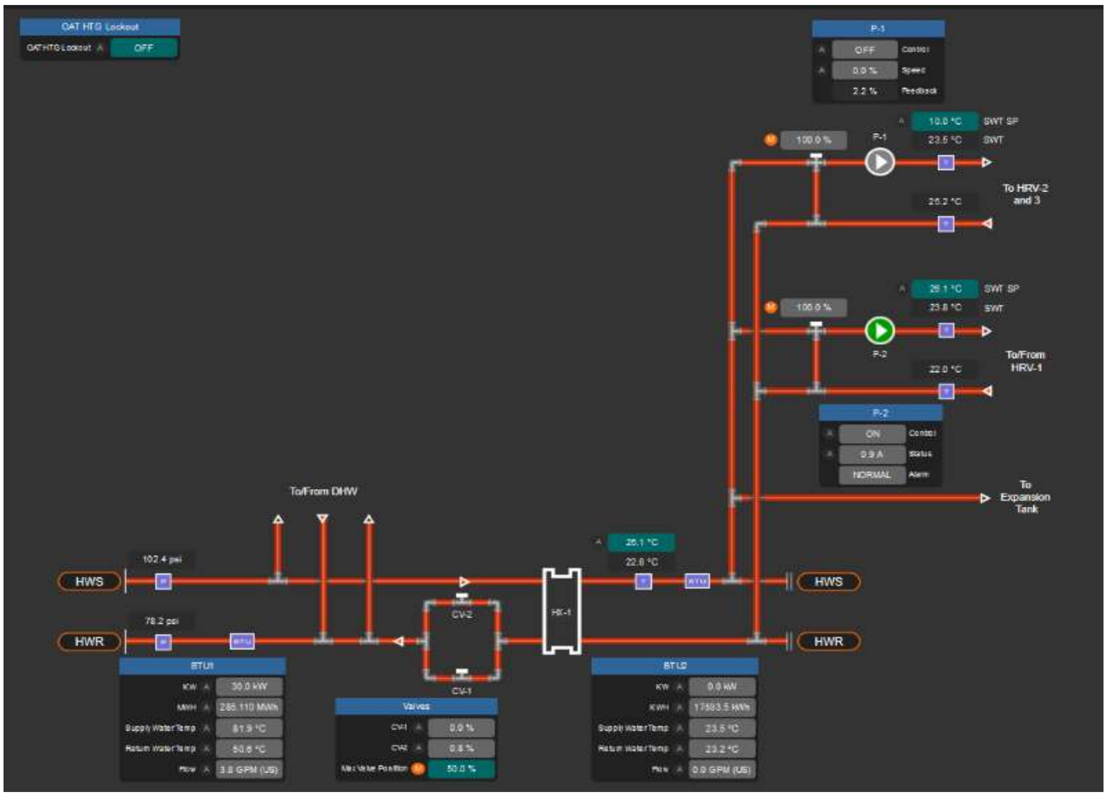


Figure 3. BMS- Domestic hot water

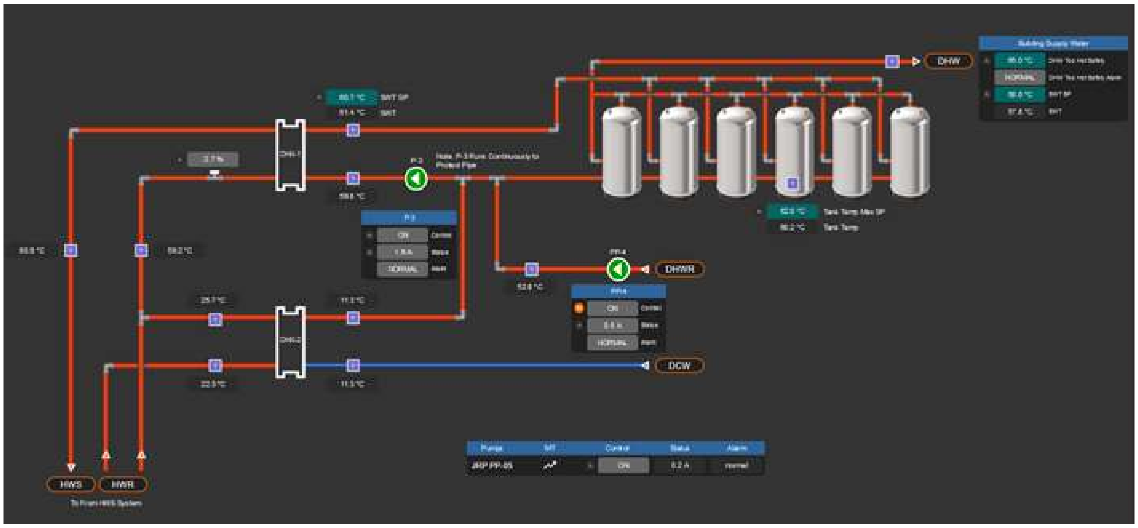
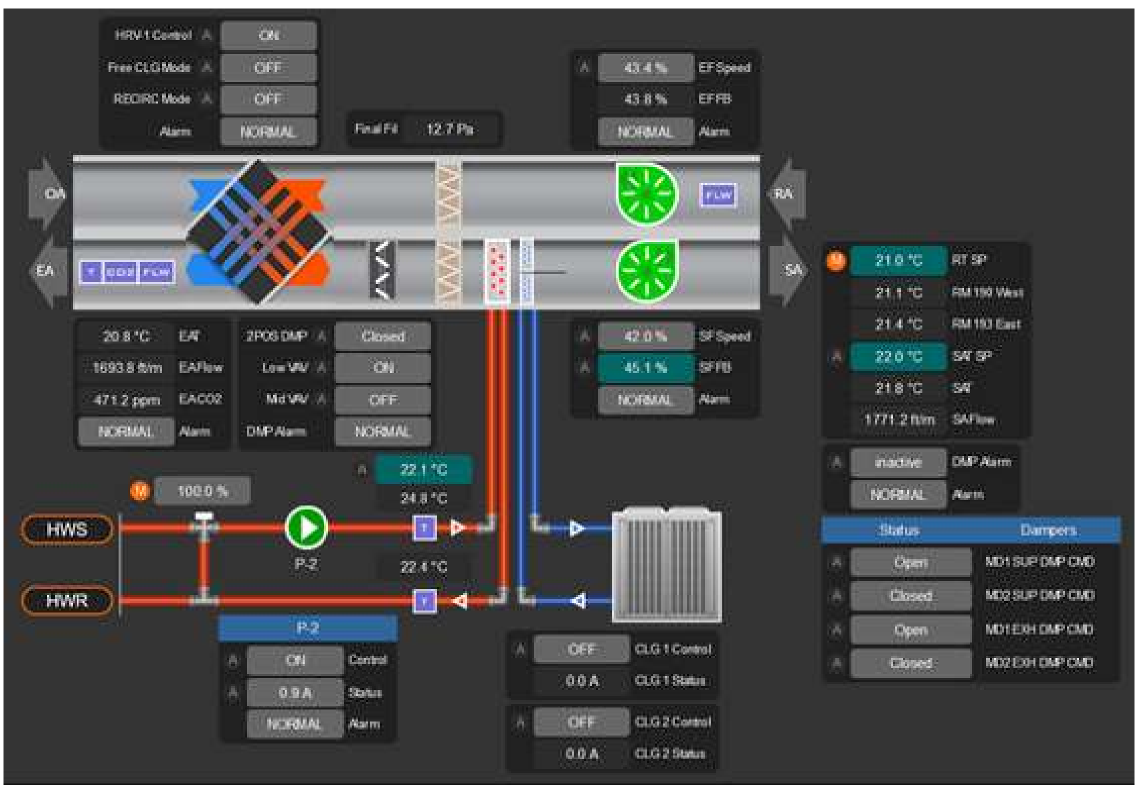


Figure 4. Heat recovery ventilator



Finally, after identifying the sub-meters corresponding to the targeted building, the relevant data for hot water consumption were downloaded from the SkySpark system. The data are then analysed in order to calculate the difference in energy consumption after the campaign period with respect to the baseline period.

6. Data Analysis

6.1 Assumption

- Students would not have been aware of the campaign initially, as the face-to-face engagement was ramped up only in the first week (September 18-24). CBSM studies explain that posters alone do not yield results and that more energy change is expected from the social diffusion methods such as face-to-face engagement and social media.
- Students' hot water behaviour for other end-uses (kitchen, laundry, taps, etc.) remains constant during this period.

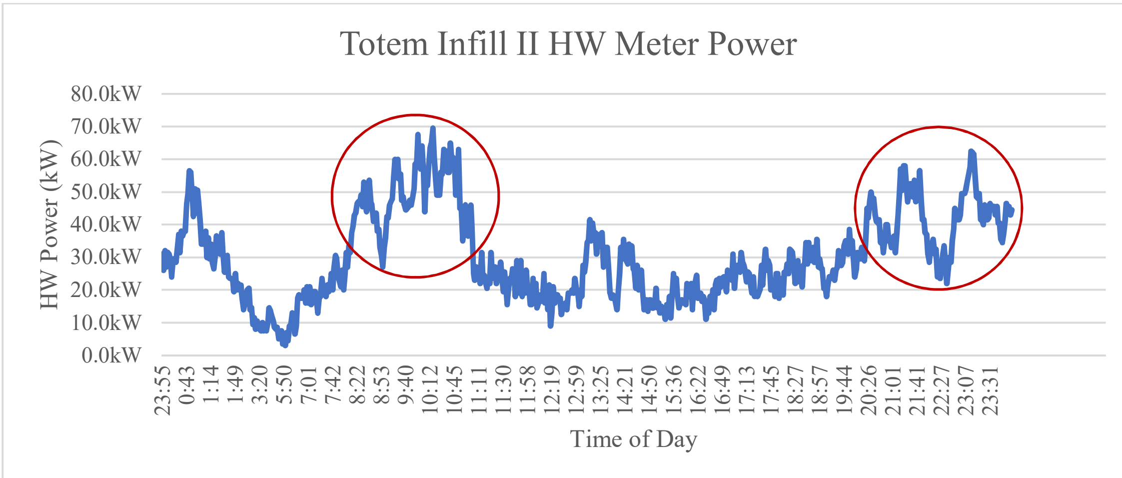
6.2 Measurement and Verification

Much of UBC's energy and water usage can be found on a cloud-based Building Information System (BIS) called SkySpark. The first step was to download the district hot water power data for the period before the start of the behaviour change campaign for the baseline data. The baseline period of September 24-October 15 was selected based on occupancy patterns related to the start of the academic year.

The campaign period of October 22-November 12 was selected, as much of the campaign ramp-up and face-to-face engagement from student volunteers and resident advisors began in the first week of the campaign. The district hot water power data for this period was also downloaded from SkySpark.

A daily student profile can also be observed in Fig. 5. The daily hot water profile for the occupants indicates peak usage between 08:30 AM – 10:30 AM and 09:00 PM – 01:00 AM and low consumption during the middle of the day between 10:30 AM – 09:00 PM.

Figure 5. Daily hot water consumption trend



Based on this information, the comparison between the baseline and campaign hot water power data was done (Fig. 6) and the data were analysed (Fig. 7).

Figure 6. Baseline vs campaign hot water power

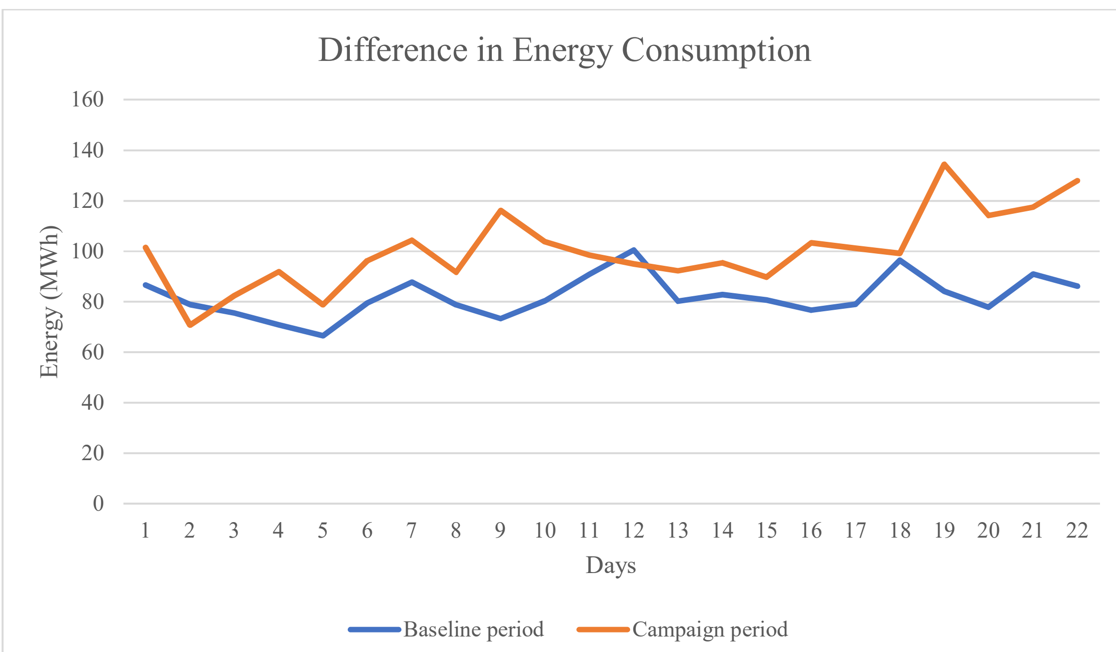


Figure 7. Savings calculation

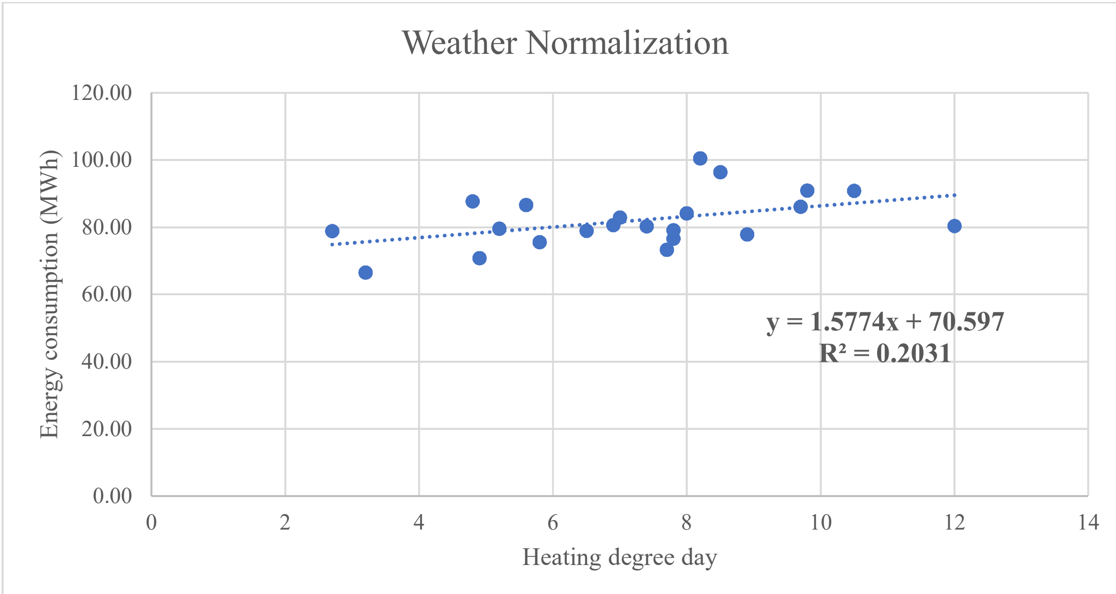
Baseline Period	HW Energy (MWh)	Campaign Period	HW Energy (MWh)
24-09-2018	87	22-10-2018	102
25-09-2018	79	23-10-2018	71
26-09-2018	76	24-10-2018	82
27-09-2018	71	25-10-2018	92
28-09-2018	66	26-10-2018	79
29-09-2018	80	27-10-2018	96
30-09-2018	88	28-10-2018	104
01-10-2018	79	29-10-2018	92
02-10-2018	73	30-10-2018	116
03-10-2018	80	31-10-2018	104
04-10-2018	91	01-11-2018	98
05-10-2018	100	02-11-2018	95
06-10-2018	80	03-11-2018	92
07-10-2018	83	04-11-2018	95
08-10-2018	81	05-11-2018	90
09-10-2018	77	06-11-2018	103
10-10-2018	79	07-11-2018	101
11-10-2018	96	08-11-2018	99
12-10-2018	84	09-11-2018	134
13-10-2018	78	10-11-2018	114
14-10-2018	91	11-11-2018	117
15-10-2018	86	12-11-2018	128
Total	1804 MWh	**Total**	2206 MWh
	Difference	**-402 MWh**	

6.3 Weather Normalization

Weather normalization was considered to offset the increase in energy consumption due to the heat recovery ventilator, as part of the hot water supplied to the building was utilized for heating.

In Figure 8, it can be observed that the R^2 value (used to assess the strength of the correlation) was 0.203. This correlation indicated a poor relation between the energy consumption data, and the daily heating degree day.

Figure 8. Weather normalization



7. Results

Based on the initial analysis, there were no quantifiable savings as a result of this campaign. An increase in hot water energy consumption was identified, despite weather normalizing to eliminate any effect of the hot water used for building heating.

It is unclear whether a change occurred in the occupancy behaviour with regards to hot water consumption. This is primarily due to the fact that the impact of the building heating could not be isolated to study the consumption data further.

8. Recommendations

Based on the above findings, below are a few recommendations for action:

- Further submetering is required to isolate the shower hot water usage. A sub meter exists for the heating energy going to the HRV, but this sub meter is not connected to Skyspark. The specific domestic hot water energy usage could be calculated if this sub-meter was available.
- Initial work has begun on a pilot study for the installation of a number of individual shower energy meters. This would allow a much better understanding of specific shower behaviour before and after future campaigns without the potential influence of other behaviours and domestic hot water variables.

Below are a few recommendations for research:

- The shorter shower campaign targeted five residences in total. This measurement investigation project focused only on one of these. There is potential for reviewing this campaign with other buildings.
- Extended research would also allow for a sensitivity analysis of the campaign to be conducted and would provide more detailed resolution to the campaign by identifying key tactics of the campaign which provide the best results.

REFERENCES

International Energy Agency (2010). "World Energy Outlook 2010" International Energy Agency, France.

International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings, Volume I (Revised). (2002). doi:10.2172/15000242

Lima, Carlos Alberto Fróes, and José Ricardo Portillo Navas. "Smart Metering and Systems to Support a Conscious Use of Water and Electricity." Energy, vol. 45, no. 1, 2012, pp. 528–540., doi:10.1016/j.energy.2012.02.033.

"Linear Regression Analysis of Energy Consumption Data." Degree Days - An Introduction, www.degreedays.net/regression-analysis.

Lopes, M., Antunes, C., & Martins, N. (2012). Energy behaviours as promoters of energy efficiency: A 21st century review. *Renewable and Sustainable Energy Reviews,16*(6), 4095-4104. doi:10.1016/j.rser.2012.03.034

McKenzie-Mohr, D. (2011). Fostering sustainable behavior: An introduction to community-based social marketing. Gabriola Island, BC: New Society.

Minnesota Department of Commerce- Division of Energy Resources (2015). "Energy Efficiency Behavioural Programs: Literature Review, Benchmarking Analysis, and Evaluation Guides." Minnesota, US

Thaler, R. H., & Sunstein, C. R. (2009). Nudge: Improving decisions about health, wealth, and happiness.

Wilson, C., & Dowlatabadi, H. (2007). Models of Decision Making and Residential Energy Use. *Annual Review of Environment and Resources,32*(1), 169-203. doi:10.1146/annurev.energy.32.053006.141137