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Effectiveness of multiu family hot and cold water subu metering of buildings in University Neighborhoods Association (UNA) neighborhoods

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Executive Summary

In 2009 the average water usage in British Columbia was 353 liters/day/capita for residential costumers, including both single-family homes and multi-residential buildings (MURBs). However in municipalities with volume-based water charges, enabled by meters, the average residential consumption rate was significantly lower at 229 liters/capita/day. Although metering with commercial costumers is more widespread, the use of water meters has increased over the past few decades nationwide and has already reached one third of the residential sector in British Columbia.

To ensure lower consumption of water, among other resources, and for more efficient energy use performance compared with standard counterparts, all residential buildings on campus constructed after 2006 have to comply with UBC's building rating system, the Residential Environmental Assessment Program (REAP). However, as in the case of the US Green Building Council's LEED® Green Building Rating System, REAP does not guarantee optimal performance in the post-occupancy phase.

This project was undertaken in partnership with the University Neighbourhoods Association (UNA), the UBC Campus Sustainability office and UBC Properties Trust to assess sub-metering technology performance in UBC's multi-residential buildings. This was done using actual consumption data for total water consumption from UBC Utilities and from suite meters' readings, in addition to other relevant information such as building floor plans and record drawings. The main purpose of this study is to analyze water consumption of six UBC's faculty and staff housing buildings (two of them with a hot/cold water sub-metering system installed) and three market rental buildings within campus and UNA jurisdiction. In addition, the project explores the environmental and cost effectiveness of making people aware of their actual consumption, through sub-metering, and whether it might have an important role in fostering water conservation.

The average total water consumption for the sub-metered buildings was found to be 330 liters/day/unit and for non-metered buildings was 612 liters/day/unit. The average hot water consumption for the sub-metered buildings was found to be around 130 liters/day/unit, with no significant differences between charging tenants and just informing them about their water use. For a more accurate usage analysis on hot water savings, temporary individual suite meters for domestic hot water on selected units on baseline buildings would be required.

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1 Introduction

UBC Properties Trust and the University Neighbourhoods Association (UNA) aim to incorporate innovative and sustainable development technologies with a focus on energy conservation, reducing water consumption, providing good indoor air quality and making use of sustainable construction practices in their residential projects.

1.1 Objectives

The purpose of this project is to determine the technical and economic effectiveness of hot and cold water sub-metering as a means to save water and reduce energy and greenhouse gas (GHG) emissions in an effort to support UBC, UBC Properties Trust and the UNA in reaching their sustainability goals. The study will focus on multifamily homes where the UNA is responsible.

1.2 Background

The UNA actively works to engage with the residents and UBC to foster sustainable operation and maintenance of the housing and community facilities within the neighborhoods under its jurisdiction. One area of interest is to better understand the effectiveness of sub-meters on hot and cold water in multi-unit residential buildings (MURBS). Currently, individual sub-meters are installed in some UNA buildings. These buildings include buildings 1 through 3 of this study. Enerpro is monitoring the first two buildings and charging tenants for hot water only. QMC Metering Solutions and UBC Properties Trust have been monitoring the building 3 since November 2011 for hot and cold water consumption; tenants are not being charged but know that there is potential for future charges on water usage.

Buildings 4 and 5 started operations in July 1st, 2012. Similar to building 3, these edifices are being monitored by QMC and UBC Properties Trust for cold and hot water without directly charging tenants; there is potential for future billing. Buildings 4 and 5 will be the first UBC faculty & staff rental buildings to be sub-metered and monitored within UNA neighborhoods. The previous three buildings above are all rental market buildings.

For benchmarking purposes, non-metered control edifices are included in the analysis. Buildings being considered are faculty and staff housing buildings (buildings 6 to 9).

1.3 Village Gate Properties

Faculty and staff housing was first developed in the period between 1991 and 1994 by UBC Properties Trust in order to fulfill the requirements of new faculty and staff at UBC (Village Gate Homes, 2012). In this preliminary phase, 268 rental units were built in the Fairview and Acadia area.

In 2001, Phase 1 buildings were constructed by UBC Properties Trust to continue with the Faculty and staff housing plans. The former one consisted of 11 low-rise town houses and the latter of two-level town houses and one and two bedroom apartments. One year later Village Gate Homes was founded as a management entity for these rental housing developments and Phase 2 was completed. This stage provided additional 36 apartment units, including one to three bedroom units.

Phase 3 buildings were completed in the summer of 2004 and commissioned in early 2005. This phase consists of 60 suites, of different configurations ranging from one to three bedroom units. The next stage (Phase 4) was completed in late 2006 and Phase 5 completed three years later.

The latest additions to the family of developments (2012) from Village Gate Homes saw the completion of two residential buildings on the west side of Wesbrook Mall. The first one includes 60 one to three bedroom suites and the second one 47 one to three bedroom suites.

1.4 University Neighbourhoods Association (UNA)

The University Neighbourhoods Association was established in 2002 to provide municipal-like services for its residents and to support the growth and sustainable aspects of the UBC community. The planning originated in the 1990's and aimed to create a university community that would offer housing and activity options for UBC faculty, staff and students. At the same time it was important that the UNA was able to raise money for the University Endowment Fund by hosting community events throughout the year.

The UNA is incorporated under the British Columbia's Societies Act and is governed by a board constituted of eight members. As of 2012, the UNA has around 3,000 members and represents roughly 8,000 residents in five neighborhoods: Chancellor Place, East Campus, Wesbrook Place, Hampton Place and Hawthorn Place.

One of the UNA's main objectives is to promote sustainability within these five neighborhoods.

1.5 UBC Residential Environmental Assessment Program (REAP)

REAP is UBC's specific sustainable building rating system, that is mandatory for all new residential construction on campus. REAP can be applied to both low and high-rise buildings (UBC Campus Sustainability Office, 2009).

The beta version of the program was launched in 2005 as a result of the collective work of UBC Properties Trust, UBC Architecture professor Dr. Ray Cole and his students, Campus & Community Planning, and the Campus Sustainability office. In the following year REAP was applied to nine projects on campus to evaluate the system. The current version (REAP 2.1) was released in 2009 and takes into account the guidelines of the US Green Building Council's LEED® Green Building Rating System and the building codes of British Columbia and the City of Vancouver (Campus & Community Planning, 2009). By doing this, UBC anticipates that REAP projects evaluated will outperform similar buildings in the Metro Vancouver area by lowering water and energy consumption, increasing indoor air quality and reducing environmental impact.

Program credits are awarded in seven categories, according to the building performance. The categories are: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Construction, Indoor Environmental Quality and Innovation and Design. After fulfilling the mandatory credit requirements, UBC residential developers can choose from a wide variety of optional design credits to increase their total score.

1.6 Literature Review

Lack of motivation on the part of the landlord to save money on energy expenses is a common barrier to efficient energy and water usage, because the avoided cost of energy benefits only the tenant. According to an International Energy Agency (IEA) report (IEA, 2007), energy efficiency operations involving a principal (tenant) and an agent (landlord or manager) result in the problem of goal divergence. This issue is the consequence of the parties' interests conflicting with each other, for example, a landlord wanting to minimize capital cost and a tenant wanting to minimize energy cost. This project will clarify and help understand solutions to these barriers and uncover opportunities to reduce water and energy consumption.

At present, there are some studies on sub-metering for commercial, residential and institutional properties. However, compared with other energy conservation technologies and methods there is still very little information on the topic. A better understanding of the benefits and best practices of the technology will be greatly beneficial to UNA residents and will be a valuable reference for future studies and research.

Prior to this project, studies confirmed annual water savings from sub-metering.

Sub-metering is metering that occurs downstream of a water utility master meter. It usually entails having a billing system in each apartment in a multifamily dwelling to determine actual water consumption using one or more water meters. Normally, a multi-family complex has either one master meter for the entire development or a meter for each building. Therefore the building owners/managers are responsible for the whole water utility bill; the total expense is uniformly divided between the number of suites and passed on to tenants via rent, association fees, or other forms of payment. Changing to sub-metering implies that not just environmental benefits can be achieved, but also economic ones. By 2006, 32.6% of residential clients and 81.7% of industrial/commercial clients were metered in British Columbia (Environment Canada, 2010).

Making people aware of their actual consumption through sub-metering might have an important role in fostering water conservation. In 2010 a survey was undertaken by RBC and Unilever Canada, it found that the average Canadian perceived water consumption per capita to be an average of 79 liters per day (RBC and Unilever Canada, 2010). Nonetheless, the 2009 Municipal Water Use Report survey shows that in municipalities with volume-based water charges enabled by meters, the average residential consumption rate was 229 liters/capita/day and in municipalities lacking metering the average residential consumption rate (including both single and multiple family homes) was higher at 274 liters/capita/day (Environment Canada, 2011). Specifically in British Columbia, the average water usage for that same year was around 353 liters per capita per day for residential costumers, while five years earlier metered residential costumers in the province had already achieved a 266 liters per capita per day value (Zapp, 2010).

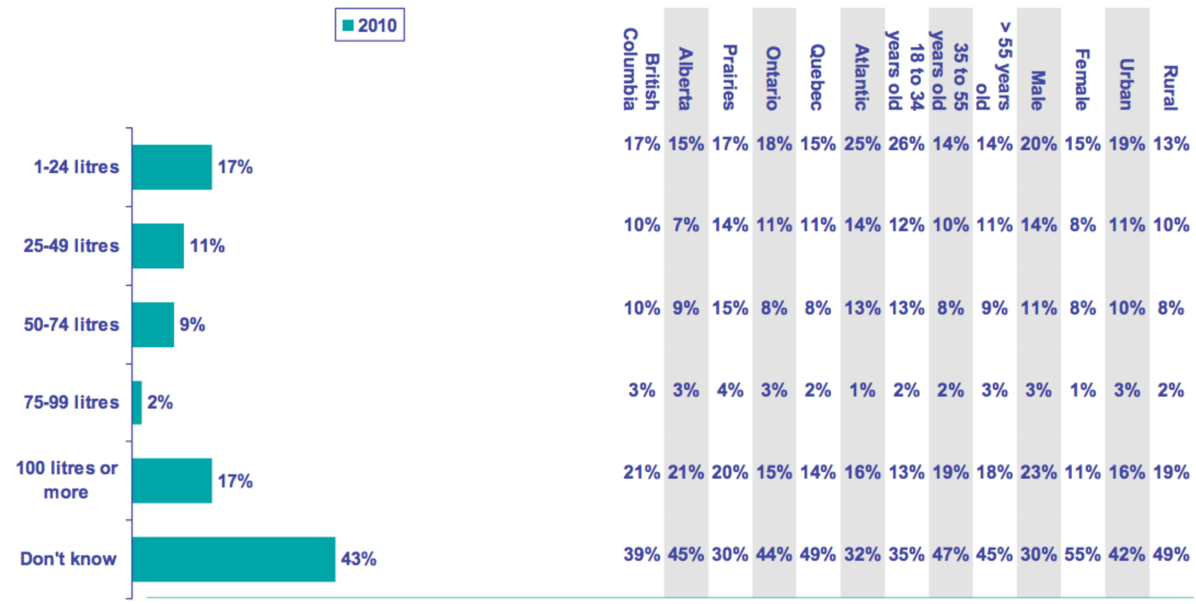

Figure 1 Perceived total amount of water for personal use in Canada, liters/day/capita (RBC and Unilever Canada, 2010)

According to the 2007 Santa Clara Water District study (Morvay, 2007), once residents became aware of their utility usage through individual metering, the total consumption went down by 22% in four mobile home parks in Santa Clara County.

In 1999 Environment Canada found that flat rate customers used 70% more water than metered customers with volume-based rates (Environment Canada, 2011). Although conventional bulk metering provides reductions in water usage compared to no metering, sub-metering takes a step further.

One of the most relevant studies related to sub-metering is the National Multiple Family Sub-metering and Allocation Billing Program, conducted in the United States in 2004. According to this report, roughly 85% of apartment properties still include water in the rental fees. In addition, the research found that billing residents in rental properties for their water usage, separately from their fees, could achieve an average of 15% annual reduction in water consumption by direct metering in the apartment sector. This information suggests that a great conservation potential exists by implementing sub-metering programs in multi-family residential buildings (Mayer, Towler, & DeOreo, 2004) and making residents explicitly aware of water charges.

A Brazilian study (Yamada, Prado, & Ioshimoto, 2000) verified a similar figure: 17% reduction in water consumption from water sub-metering in residential buildings. The average monthly water consumption per apartment in buildings with collective metering was 703 liters/day/apartment. In contrast, buildings with individual metering schemes averaged consumption of 587 liters/day/apartment, shown in Figure 2.

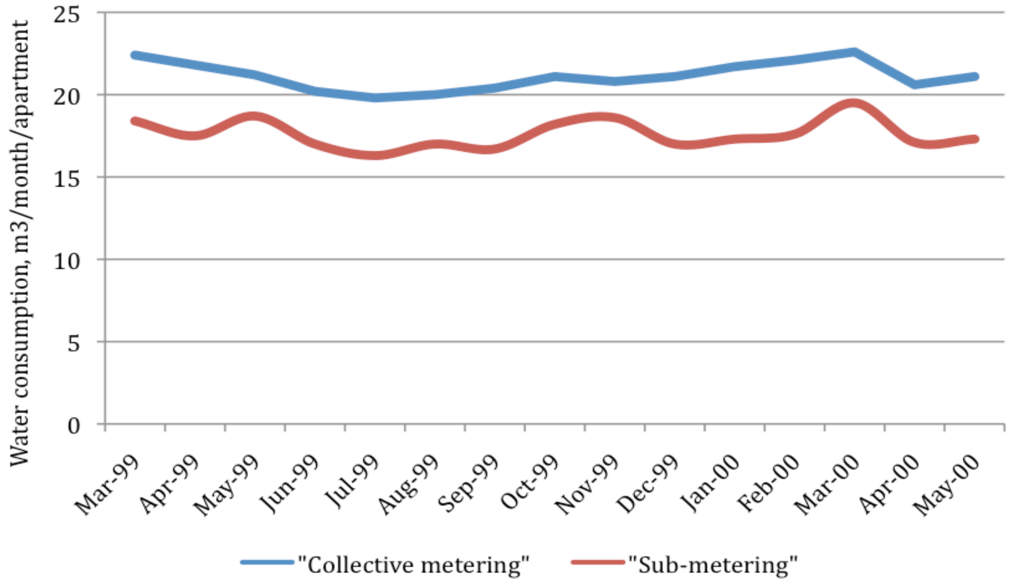

Figure 2 Water consumption at Guarulhos municipal district in Sao Paolo, Brazil (Yamada, 2000)

In addition, this study also analyzed the buildings' average resident actions and habits that increased water wasteful usage. All identified habits were reduced with the introduction of sub-metering devices, mainly the most significant ones: Taking long showers, cleaning teeth with open faucet and flushing the toilet more than once. Reductions in frequency are clearly displayed in Figure 3 below.

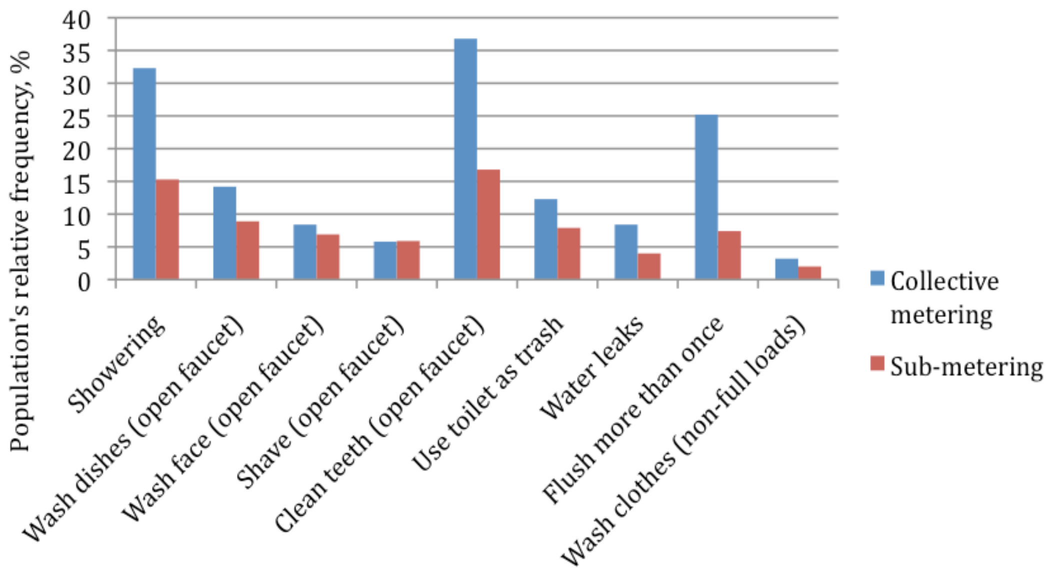

Figure 3 Water user procedures and habits (Yamada, 2000)

A case study from the University of Queensland in Australia (N. Price, 2010), explored participants' perceived efficiency of different types of water saving measures in commercial and industrial buildings. Increasing building occupants' awareness and training, including initiatives like displaying signage, highlighting consumption levels and incentives, was perceived by survey participants (27% of the total) as the most effective way to save water. Participants also highlighted sub-metering and monitoring as the second most effective method (Figure 4).

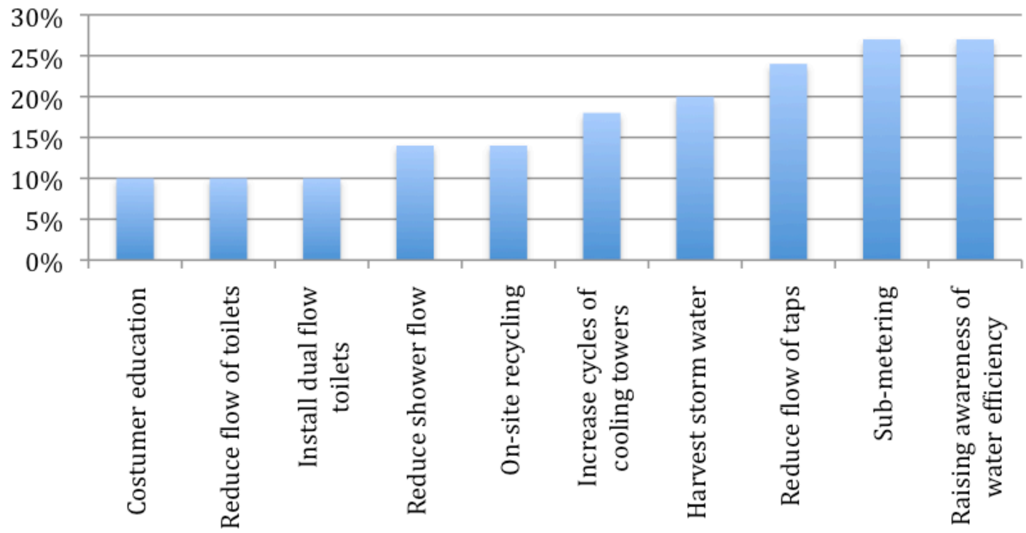

Figure 4 Water conservation measures considered by participants to be most effective (N. Price, 2010)

These results are promising, however sub-metering information and feedback mechanisms should be customized to target specific users in order to effect operational and behavioral change from a building wide perspective.

2 Data and Methodology

2.1 Data Collection and Sources

In order to produce the best outcome from this study it was important to obtain data that was as complete and accurate as possible for the analysis. As a first step, the scope of the project delineated the amount and level of data that was needed. The decision was made and four faculty and staff buildings with no sub-meters were selected as baseline or control buildings, while three market rental buildings and the two newest faculty and staff buildings were selected as target study samples (sub-metering). For the baseline buildings the data available was mainly total water consumption provided by UBC Utilities. For the sub-metered edifices, three different sources of water consumption information were available: total water consumption from UBC Utilities bills, hot water consumption per suite from Enerpro bills (hot-water sub-metered buildings) and hot/cold water consumption per suite from QMC information (hot/cold water metered buildings).

After obtaining the data by contacting the appropriate utilities or service providers, sub-metered readings and datasets were assembled and analyzed. Other important data was obtained through the UBC Campus Sustainability office and UBC Properties Trust with the proper authorization. This included floor plans, DHW systems and some water fixtures data sheets as well.

All available data was requested since the properties were commissioned. In optimal conditions a multiannual utility usage data analysis is encouraged, but for this project not all buildings fulfilled this requirement and the evaluation metrics had to be adjusted in order to assess the performance of these complexes in the best possible manner.

UBC Utilities provided total water consumption data for all properties, managed by Village Gate and Wesbrook Properties. Data was requested and provided by Ms. Erin Kastner, Geospatial Information Manager at UBC Utilities. These measurements are collected by a single meter for the entire building and cover the total water usage, including hot and cold water for residential purposes, irrigation and in some cases other water features.

As mentioned above, for the purpose of this project all dimensional measurements (i.e. square footage, number of bathrooms and units) were obtained from record drawings (i.e. Architectural, Mechanical) and floor plans were obtained from the Wesbrook Properties and Village Gate Homes websites and also provided by Mr. Kyle Reese (Community Energy Manager at the UBC Campus Sustainability office) and Chadwick Choy (Development Assistant at UBC Properties Trust). No common areas were included in the analysis. The number of units is quite important as it enables calculations related to water consumption per suite, which makes it easier to compare water usage among different buildings. The total square footage information is also significant as it allows comparisons based on actual suite size. In this case, where buildings are not the same it is crucial to identify similarities in order to match and compare them in the most suitable way. Additional information, which helped correspond buildings, is the date of commissioning, the number of storeys, the type and size of suites and the number of suites.

It was agreed that the selected period of time for the study would cover the period from

September 2011 to August 2012. Data sources and information provided for this project include:

- Quarterly total water consumption data for faculty and staff housing buildings and UNA market rental buildings from UBC Utilities.
- Separate monthly hot and cold water consumption readings on all rental units with hot and cold meters and owned by UBC Properties Trust, since sub-meters started operations.
- Monthly hot water consumption data on all rental units with hot-water only meters and owned by UBC Properties Trust, since sub-meters started operations
- Floor plans and units area of all buildings from the UBC Campus Sustainability office.
- Technical information on DHW systems and water fixtures of all buildings from UBC Properties Trust and the UBC Campus Sustainability office.
- Cold water meters for irrigation, water features and parking hose bib in Granite Terrace.
- Approximations on occupancy of the buildings based on US Green Building Council's LEED® Green Building Rating System guidelines.

2.2 Methodology

The first step was to select the study buildings. Five rental multi-residential buildings (MURBs) with sub-metering technology installed were initially selected for analysis within UBC campus. Three of them were low-rise four-storey buildings (buildings 3,4 and 5); was a mix of townhomes and apartments building (building 1), and a three-storey apartment building (building 2). The first three have cold and hot water separate meters in place and the last two have hot water only suite-meters instead. It should be noted that only buidings 1 and 2 have implemented volume based hot water billing to tenants, while water fees are still included in the rent for all faculty and staff housing including buildings 3, 4 and 5.

All of these buildings were completed after 2006 and are certified by UBC's proprietary rating system REAP, which became mandatory for all new construction taking place on campus after this year (UBC Campus Sustainability Office, 2009).

After the buildings selection was complete, the second stage was to decide on which buildings should be used as a control or baseline for the project. Four faculty and staff rental MURBs constituted the best choice for the study: buildings 6 to 9.

Figure 5 UNA buildings and metering schemes

The first one is a two level town house complex, two of them are low-rise four-storey buildings and the fourth one is a mixed townhome and apartment building. All of them were completed in the 2000's. Only building 8 was certified with a REAP rating; the older three did not have to adopt REAP, as they were completed prior to the establishment of the rating system in 2006. **Error! Reference source not found.** shows a summary of characteristics and water metering systems of the buildings involved in the study. After completing the selection stage, data collection was conducted. Public information on total, cold and hot water consumption for the buildings involved in this study was unavailable. The main sources of information on water consumption were UBC Utilities and UBC Properties Trust, while information on sub-metered buildings was available through Enerpro and QMC. Afterwards data was analyzed to calculate the total water consumption (per month and annually) and the water consumption intensity of the buildings, liters/day/unit, is based on total water used per year, covering the period between September 2011 and August 2012 (except buildings 4 and 5), and number of suites within the buildings. To give perspective to the study and to compare water usage with other jurisdictions, another metric was introduced, liters/day/capita. This was determined by occupancy in the buildings based on US Green Building Council's LEED® Green Building Rating System guidelines.

Potential savings were estimated on economic (CAN$) and environmental terms (tonnes of CO_2 equivalent), as well as water use (liters/day/unit and liters/day/capita).

2.3 Data Analysis Procedure

The evaluation of water consumption of MURBs commonly involves the quantification of total annual water consumed, monitored by a bulk meter in the complex. This total water value normally includes residential uses, such as showering, laundering, dish washing, toilet flushing, and irrigation. However, water consumption by end use was not part of the scope of this project, and therefore is not included in this report due to data limitations. UBC Utilities issues water bills on a quarterly basis, which required some adjustments to make them comparable to monthly sub-metering reports. This was necessary as the quarterly periods used to invoice water consumption for the buildings considered different time frames, from 29 to 123 days. For normalizing data, the quarterly information was translated into a per month basis, then divided by the days in each month and finally by the number of units in each building. After doing this, the resulting intensity of water consumption in liters/day/unit was used to compare buildings in the study; monthly and annual water consumption in liters/day/capita were also used at some points of the analysis, as mentioned above.

For this study, the possibility of analyzing hot and cold water individual suite water consumption was enabled in some buildings. Enerpro and UBC Properties Trust (in partnership with QMC) provided the data on individual dwelling consumption on a monthly basis, which is comparable to the monthly total water consumption figures previously mentioned. Enerpro's technology scheme makes hot water data available for each suite, while QMC's scheme supplied data on hot and cold water consumption for each unit. Water consumption values were represented either in cubic meters (m^3) or cubic feet (ft^3). To enable equivalent comparison with similar previous studies, liters (L) are used throughout the whole report. Not all buildings have more than one year of data, but when multiple years of data are available, annual and monthly patterns were reviewed to assess individual building progress since commissioning and uncommon events. The evaluation of the buildings also considered the description of other features that could impact water consumption. These features included the size and configuration of the apartment area, the number of suites, the domestic hot water (DHW) systems, the efficiency of water fixtures (when available), the year of commissioning, seasonal changes and estimated occupancy.

Natural gas is used for DHW heating in all buildings included in the project (some of them also have rejected heat and geothermal systems) and therefore reductions in gas consumption is reported in gigajoules (GJ) and avoided emissions in tonnes of CO_2 equivalent. Rated input and output values for the DHW systems, shown in BTU/hr as per the manufacturer data sheet, were adjusted to actual performance based on feedback from the UBC Campus Sustainability office. Savings on thermal energy were based on hot water savings estimates and were not compared against actual gas invoices for the buildings due to the lack of time.

3 Results and Discussion

This section of the report displays the general description and performance of each building individually and as groups (suite-metered and bulk-metered).

The suites in all buildings range from 450 ft^2 (42 m^2) to 1,390 ft^2 (129 m^2) in size, with a total of 11 to 126 dwellings per building. The description of each building is summarized in below and is further detailed in the following sub-sections.

Table 1 Buildings involved in the sub-metering study

Building	Water Sub-metering	Direct tenant billing	Building type	Year of commission
Building 6 (Baseline)	No	In-rent	Town houses + apartments building	2009
Building 7 (baseline)	No	In-rent	Town houses or/and big apartments	2001
Building 8 (Baseline)	No	In-rent	4 storey building (> 60 apartments)	2007
Building 9 (baseline)	No	In-rent	4 storey building (< 60 apartments)	2005
Building 1	Hot	Yes	Town houses or/and big apartments	2007
Building 2	Hot	Yes	Town houses + apartments building	2009
Building 3	Hot/cold	In-rent *	4 storey building (> 60 apartments)	2011
Buildings 4 & 5	Hot/cold	In-rent *	4 storey building (> 60 apartments)	2012

* Inhabitants are not currently being billed for their actual volume consumption, but know they can be potentially billed in the near future.

3.1 Non-sub-metered Buildings (Baseline)

Four faculty and staff buildings within UBC campus were chosen as baseline buildings for the project: buildings 6, 7, 8 and 9 (Village Gate Homes, 2012). All of them are being managed by Village Gate Homes. The construction completion date of Building 8 was January 2007, Building 6 was December 2009, Building 7 was July 2001 and Building 9 was January 2005. More detailed information on the characteristics of these buildings can be found in Appendix A: Table A 1. Tenants in all four buildings pay their water consumption fees, which are included in their monthly rent payment, because sub-metering and volume-based billing is not available. Occupancy is assumed to be 100% at all times as faculty and staff residential complexes are in great demand and have very low vacancy rates, as reported by UBC Properties Trust.

Among the selected baseline buildings, buildings 6 and 8 show the lowest water consumption. An interesting fact is that the former has standard flow water fixtures, while the latter has newer low flow water fixtures. Water consumption data was obtained from UBC Utilities for all buildings since they began operation. Readings include an irrigation portion, which is included in the analysis and is not separately quantified for each building within this study. However, for the scope of this study only the last year of performance has been taken into consideration for analysis purposes. Monthly total water consumption averages were estimated from the quarterly readings issued by UBC Utilities.

3.1.1 Building 6

Building 6 was commissioned in December 2009 and consists of 46 units, which include 1, 2 and 3 bedroom apartments, as well as 2 and 3 bedroom two-level town houses (Village Gate Homes, 2011). The weighted average size of each suite is 1043 ft^2 (97 m^2). The approximate total area of the building is 47,960 ft^2 (4,456m^2). Each suite has the following features: dishwasher, washing machine and electric fireplaces (only for town homes). The average total water consumption at suite level for Building 6 in the period covered between September 2011 and August 2012 is 512 liters/day/unit, as outlined in Figure 6 below. Building 6 holds Silver rating in UBC's Residential Environmental Assessment Program. Hot water is included in the rent. Total water usage details for Building 6 can be found in Appendix A: Table A 5. Higher consumption trends and averages are identified for the other two older buildings 7 and 9. Both of them have standard flow water fixtures.

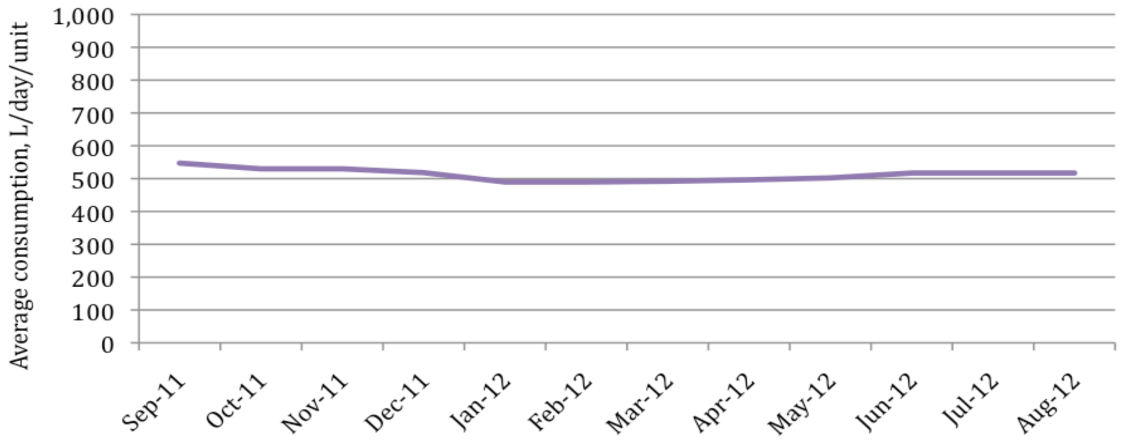

Figure 6 Building 6 average daily water consumption per month

3.1.2 Building 7

The building is comprised of 11 town homes with two different configurations, 2 and 3 bedroom options. The weighted average suite size is 1214 ft^2 (113 m^2).

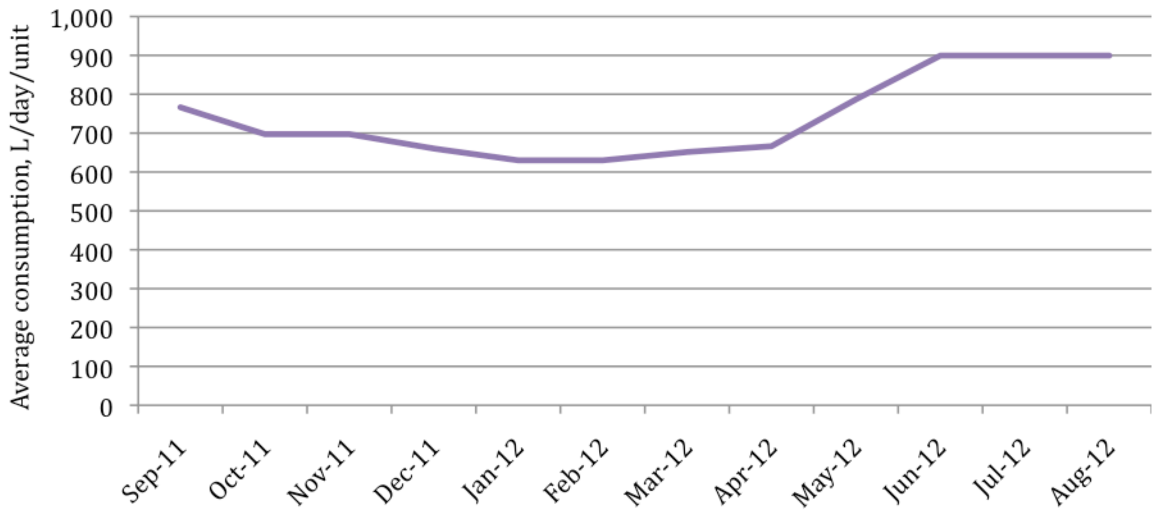

Figure 7 Building 7 average daily water consumption per month

The approximate total area of the building is 13,350 ft^2 (1,240 m^2) (Village Gate Homes, 2011). Each suite has the following features: dishwasher, washing machine and gas fireplaces. The average total water consumption at suite level for Building 7 in the period covered between September 2011 and August 2012 is 740 liters/day/unit, as outlined in Figure 7. Hot water and gas fees are included in the rent. Complete total water usage data is available in Appendix A: Table A 7.

3.1.3 Building 8

The four-storey building was completed in the winter of 2006 and commenced operations in early 2007. It consists of 71 units with four different housing options: 2 bedroom, 2 bedroom plus den and 3 bedroom apartments, and two-level town houses (Village Gate Homes). The weighted average size of each suite is 1004 ft^2 (93 m^2) and the approximate total area of the building is 71,300 ft^2 (6,624 m^2). Each suite has the following features: dishwasher, washing machine and electric fireplaces (with some exceptions). The average total water consumption at suite level for Building 8 in the period covered between September 2011 and August 2012 is 504 liters/day/unit, as outlined in Figure 6 below. Hot water is included in the rent. More detailed total water consumption information for Building 8 is available in Appendix A: Table A 6.

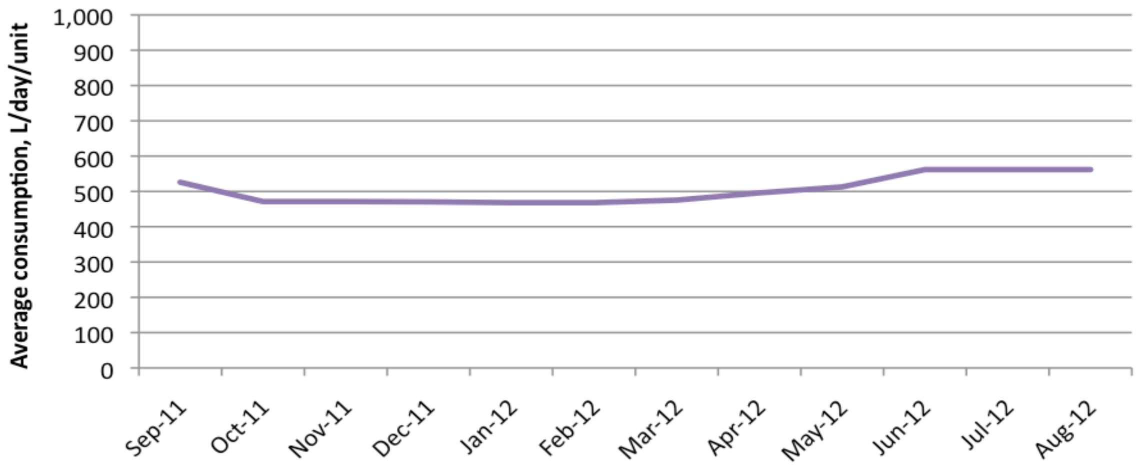

Figure 8 Building 8 average daily water consumption per month

3.1.4 Building 9

This four-storey building consists of 60 units, with different housing options: 1 bedroom, 1 bedroom plus den, 2 bedroom and 3 bedroom suites. The weighted average suite size is 831 ft^2 (77 m^2). The approximate total area of the building is 49,840 ft^2 (4,630 m^2). Each suite has the following features: dishwasher, washing machine and electric fireplaces. The average total water consumption at suite level for Building 9 in the period covered between September 2011 and August 2012 is 694 liters/day/unit; this can be seen on Figure 10. Hot water is included in the rent. Full data on water usage for Building 9 can be found in Appendix A: Table A9.

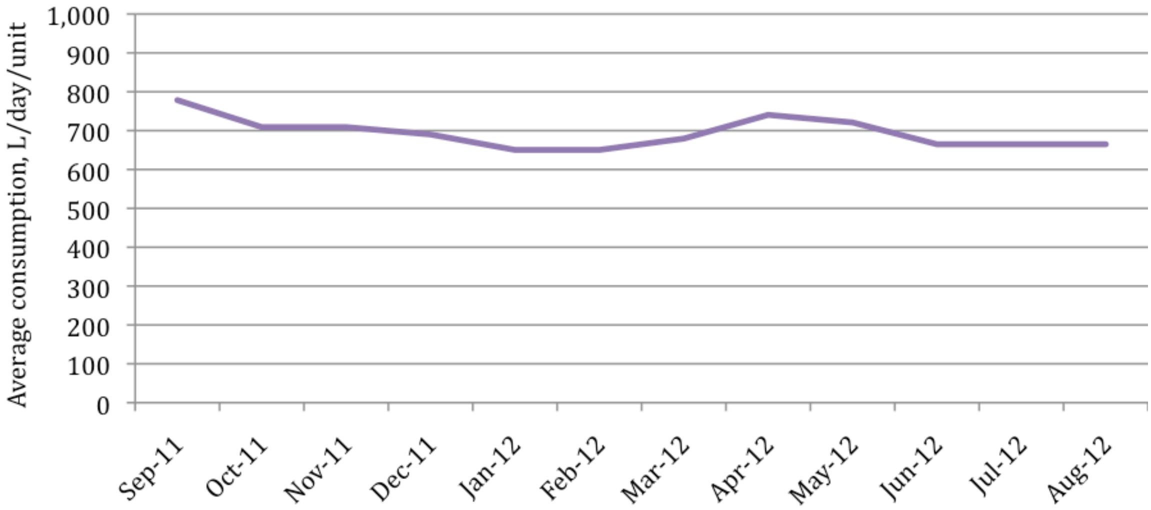

Figure 9 Building 9 average daily water consumption per month

3.2 Hot Water Sub-metered Buildings

Two market rental buildings on UBC campus were chosen as part of this study to assess hot water sub-metering with water volume consumption being directly billed to tenants: Building 1 and Building 2. They are both being managed by Wesbrook Properties and Enerpro supervises suite metering. Both of them are open to the general public to rent nonetheless UBC students and faculty or staff members also live in the buildings. More detailed information on the characteristics of these buildings can be found on Appendix A: Table A 1. Water consumption data was obtained from two sources, for both buildings since they began operation. However, for the scope of this study only the last year of performance has been taken into consideration for analysis purposes. Monthly total water consumption averages were taken from the quarterly readings issued by UBC Utilities. These readings include an irrigation portion that is not separately quantified for each building within the study. Enerpro readings provided information on hot water consumption for individual suites. Actual occupancy percentages (number of suites occupied) were possible to obtain for these two complexes and are shown in the following sections.

3.2.1 Building 1

This building was completed in 2007, consists of 126 units and offers a combination of studio apartments and 2 bedroom town homes. The weighted average size for each suite is 745 ft^2 (69 m^2) (Wesbrook Properties, 2011).

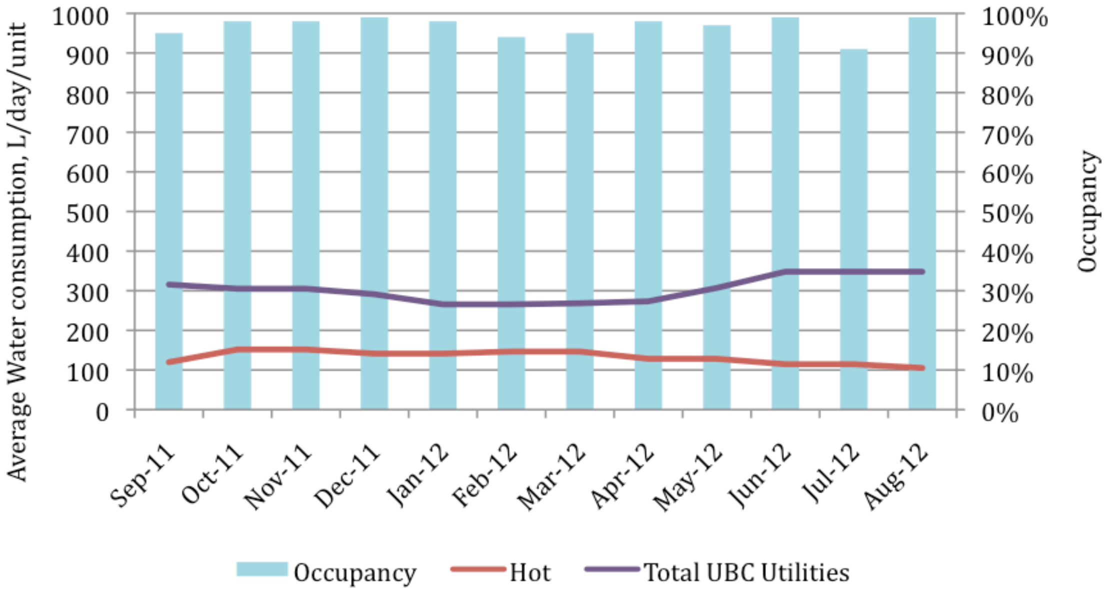

Figure 10 Building 1 average daily water consumption per month

The approximate total area of the building is 93,900 ft^2 (8,724 m^2). Each suite has the following features: dishwasher, washing machine and electric fireplaces. The average total water consumption at suite level for Building 1 in the period covered between September 2011 and August 2012 is 303 liters/day/unit. The hot water usage for the same period was on average 129 liters/day/unit; this is outlined in Figure 10 along with occupancy variations throughout the year. Hot water is monthly paid directly by the suite users to Enerpro. Building 1 holds a Bronze rating in UBC's Residential Environmental Assessment Program; as part of its sustainable features, a geo-exchange system that aids in heating domestic hot water has been implemented in the building. Full data on total water consumption for Building 1 is available in Appendix A:

Table A 3.

3.2.2 Building 2

This four-storey market rental building was commissioned in March 2009 and consists of 77 units, with housing options ranging from 1 to 3 bedroom apartments or townhouses. The weighted average size for each suite is 869 ft^2 (81 m^2). The approximate total area of the building is 66,895 ft^2 (6,215 m^2) (Wesbrook Properties, 2011). Each suite has the following features: dishwasher, washing machine and electric fireplaces.

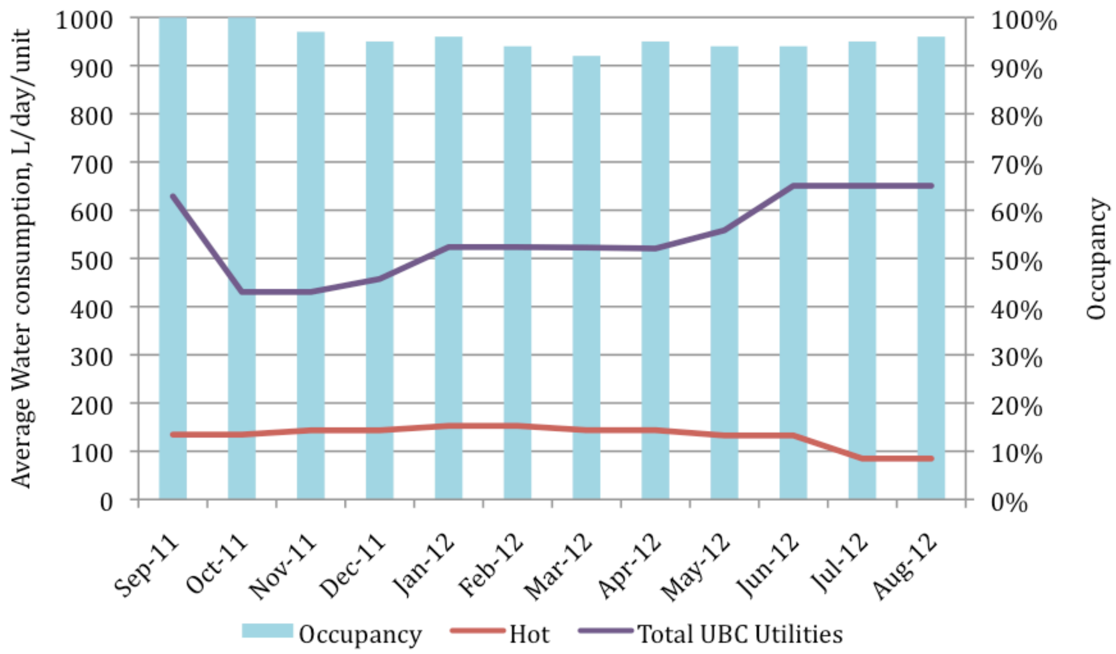

Figure 11 Building 2 average daily water consumption per month

The average total water consumption at suite level for Building 2 in the period covered between September 2011 and August 2012 is 546 liters/day/unit. Hot water usage for the same period was on average 131 liters/day/unit; this is outlined in Figure 11 along with occupancy variations throughout the year. Hot water is monthly paid directly by the suite users to Enerpro. Building 2 holds a Gold rating in UBC's Residential Environmental Assessment Program; as part of its sustainable features, a rejected heat system has been implemented. The system is used to preheat domestic hot water in the building and uses waste heat from the Save-On-Foods commercial unit. Total water usage for Building 2 can be found on Appendix A: Table A 2.

3.3 Hot and Cold Water Sub-metered Buildings

Two faculty and staff housing buildings and one market rental building within UBC campus were chosen for this category: Building 3, Building 4 and Building 5. The first two are being managed by Village Gate Homes and are the newest addition to the UBC faculty and staff properties. The latter one is open to the general public to rent and is administered by Wesbrook Properties. QMC supervises suite metering in all three edifices in conjunction with UBC Properties Trust. More detailed information on the characteristics of these buildings can be found on Appendix A: Table A 1. Water consumption data was obtained from two sources for the three buildings since they began operation. UBC Utilities readings include an irrigation portion, which is not separately quantified for each building within the study. QMC/UBC Properties Trust readings provided information on hot and cold water consumption at the individual suite level. Unfortunately just The Mews had enough data to fulfill the one-year of data requirement.

3.3.1 Building 3

This four-storey market rental building was commissioned in February 2011, consists of 72 units and offers 1 or 2 bedroom options. The weighted average size of each suite is 803 ft^2 (75 m^2). The approximate total area of the building is 57,840 ft^2 (5,374 m^2) (Wesbrook Properties, 2011). Each suite has the following features: dishwasher, washing machine and electric fireplaces. The average total water consumption at suite level for Building 3 in the period covered between September 2011 and August 2012 is 356 liters/day/unit; this is outlined in Figure 12 below along with occupancy variations throughout the year. Hot water fees are not directly billed to the suite inhabitants, but they are aware of their water consumption readings; tenants have notion that water fees can potentially be charged directly to them. Building 3 holds a Gold rating in UBC's Residential Environmental Assessment Program; as part of its sustainable features, a rejected heat system has been implemented. The system is used to preheat domestic hot water in the building and uses waste heat from the Save-On-Foods commercial unit. Full data on total water consumption for Building 3 can be found in Appendix A:

Table A 4.

Sub-meters were introduced in the suites and became operational by November 2011; hot and cold water for individual dwellings are being metered separately from each other. The approximate portion of the total water consumption that corresponds to hot water is around 44%, while the remaining 56% is cold water. Figure 12 shows the water consumption trends for the period covered between November 2011 and August 2012. The average hot water consumption was 130 liters/day/unit. On the other hand, cold water consumption for the same period was 168 liters/day/unit. The sum of these averages is the residential water portion and was 308 liters/day/unit.

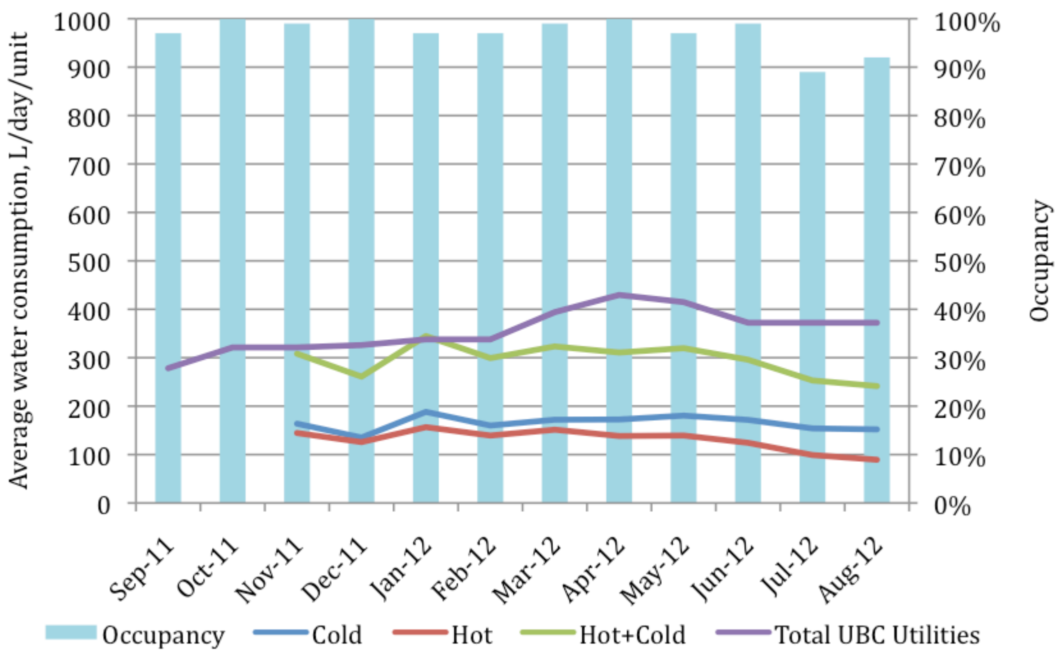

Figure 12 Building 3 Average daily water consumption per month

3.3.2 Building 4 and Building 5

These two buildings are the latest addition of faculty and staff buildings managed by Village Gate Homes and started operations in July 2012. Building 4 has 60 units and building 5 has 47 and they both offer options of 1, 2 or 3 bedroom apartments. The weighted average size for each suite is 865 ft^2 and 859 ft^2 respectively (around 80 m^2). Each suite has the following features: dishwasher, washing machine and electric fireplaces. Both buildings share a central courtyard and the approximate total area of the buildings is 51,540 ft^2 (4,788 m^2) and 40,660 ft^2 (3,777 m^2) respectively. Building 4 is fed through Building 5; hence just one reading is available for both from UBC Utilities. Hot water fees are currently being included in the rent, but separate hot and cold water suite meters are installed in all units; hot water could potentially start being billed directly to tenants in the near future.

Buildings 4 and 5 reached full capacity by August 2012, which was the last month considered in the study and reported a total water consumption of 643 liters/day/unit. Hot water consumption was 131 liters/day/unit and 171 liters/day/unit for cold water; the sum of these averages accounts for the residential total water consumption and was 302 liters/day/unit, as outlined in Figure 13. A couple of extra months of data were possible to obtain for these two buildings in order to have a better notion of their initial performance, but were not considered in the analysis stage. Full data on total water consumption can be found in Appendix A:

Table A 9.

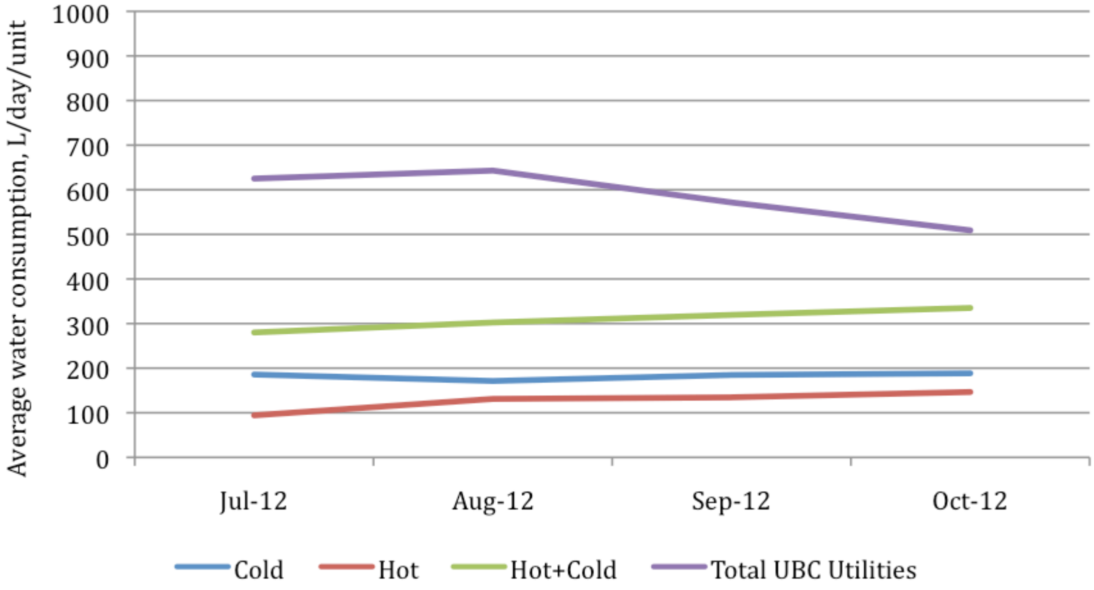

Figure 13 Buildings 4 and 5 average daily water consumption per month

3.4 Residential Water Use

Analyzing consistent data throughout the project was crucial to achieve the best possible outcome from the study. The main focus was set to be on residential water use, which was accurate for the fully sub-metered buildings for both hot and cold water (buildings 3 to 5). For hot water only sub-metered buildings, the cold water portion was not measured at the suites and had to be estimated by subtracting the hot water fraction from the total water readings provided by UBC Utilities (buildings 1 and 2). In the case of bulk-metered buildings this was not possible because the only data available was the total water reports provided by UBC Utilities. As mentioned in previous sections, these readings include irrigation and other non-residential water end uses. This is the reason why total water data was used instead of the suite readings to compare buildings in the analysis phase.

For buildings 3, 4 and 5 it was possible to make an estimation of the non-residential water portion. This is outlined in the following sections.

3.4.1 Irrigation

From building 3 data it was possible to obtain an estimate on the amount of water that was diverted to landscaping and other non-consumptive uses over period covered from November 2011 to October 2012.

Table 2 Irrigation water estimates for building 3

Month	Total water, L	Suite meters, L	Remaining water, L	Percentage
November, 2011	693,822.47	665,755.51	28,066.96	4.05%
December, 2011	727,690.30	563,500.18	164,190.12	22.56%
January, 2012	753,944.66	744,564.00	9,380.66	1.24%
February, 2012	705,303.07	646,264.43	59,038.64	8.37%
March, 2012	879,518.85	698,272.20	181,246.66	20.61%
April, 2012	927,898.91	671,089.16	256,809.75	27.68%
May, 2012	925,772.50	690,508.32	235,264.18	25.41%
June, 2012	803,937.49	639,026.72	164,910.78	20.51%
July, 2012	830,735.41	546,439.33	284,296.08	34.22%
August, 2012	830,735.41	521,258.77	309,476.64	37.25%
September, 2012	729,730.83	666,520.16	63,210.67	8.66%
October, 2012	686,960.00	672,694.17	14,265.83	2.08%

shows the quantity of water in liters that was read in both systems: bulk metering and suite-metering. The third column displays the remaining water portion, which results from the difference of the two previous readings and can potentially be allocated to irrigation. The last column represents the contribution of these values in relation to the total water consumption of the building per month. These percentages varied from season to season, tending to be higher during the summer months and had an annual average of approximately 17%.

3.4.2 Other Water End Uses

It was possible to conduct a similar analysis for buildings 4 and 5 due to the availability of total water and sub-metered readings (for hot and cold water). In contrast to building 3, these buildings showed higher differences between the metered portion (residential use) and the total water consumption of the building ( ). Presumably their water readings include not only landscaping but also feed other features. Unfortunately, by the time this study was undertaken the record drawings for buildings 4 and 5 were not available and it was not possible to have a clear idea of the plumbing network within them.

Table 3 Irrigation water estimates for buildings 4 and 5				
Month	Total water, L	Suite meters, L	Remaining water, L	Percentage
August, 2012	68,799	32,357	36,442	52.97%
September, 2012	61,157	34,182	26,975	44.11%
October, 2012	54,470	35,854	18,616	34.18%

3.4.3 Cold Water Meters

In the case of building 2 additional meters provide cold water readings for the commercial units. Also three cold water meters are installed to account for the water usage of the central fountain, irrigation and parking hose bib. These measurements represent a promising way of having a more accurate figure of the residential water use in the future. These readings can be accounted and subtracted from the total water consumption values in the reports from UBC Utilities and facilitate the calculation of a more realistic residential usage in the building. Unfortunately, these meters started operations in July 2012 and only provided a few months of data that at the time that this study was conducted was not sufficient. Nonetheless, learning of the existence of these meters is a significant advance and gives and idea of the quantity of water that ends up being used for these activities.

At the building level, the water features total water requirements reached 544 liters per day for the whole period covered between July and August 2012. No reading was available for July and August, therefore the total value for the four-month period (July-Oct) was divided by the four months; although some seasonal variations might be occurring due to evaporation during the summer months. Water usage for the parking hose bib was 454 liters per day during July and August and 121 liters per day on September and October. On the other hand, irrigation achieved the highest contribution with 14,726 liters per day on the first bimonthly reading, lowering afterwards to 6,497 liters per day on the second bimonthly period. At the suite level the impact on the total water consumption readings is shown below in .

Table 4 Non-residential Cold water meters readings for building 2				
Month	Water features, L/day/unit	Irrigation, L/day/unit	Parking hose bib, L/day/unit	Total, L/day/unit
Jul-12	7.06	191.24	5.89	**204.20**
Aug-12	7.06	191.24	5.89	**204.20**
Sep-12	7.06	84.38	1.57	**93.01**
Oct-12	7.06	84.38	1.57	**93.01**

The lack of records for non-residential water end uses represented an important issue. For this reason and to enable a fair comparison between all buildings, total water data was employed for the analysis on Section 3.5 of this report. Section 3.6 provides the results of the hot water sub-metering schemes assessment, using the readings obtained from Enerpro and QMC through UBC Properties Trust.

3.5 Total Water Consumption Analysis

Due to the nature of the project and small sample size, several comparison methods were used in the analysis: One-on-One comparison between control and sub-metered buildings, individual buildings annual total consumption averages and metered vs. non-metered buildings' monthly averages. All of them were based on the period covered between September 2011 and August 2012.

3.5.1 One-on-one Comparison

The first option to compare individual buildings to each other within the sample was to match buildings with similar characteristics such as size, number of apartments, number of bathrooms and type of suite.

Three different kinds of buildings were identified:

- Four storey building with more than 60 apartments: buildings 3 and 8;
- Four storey building with apartments and town houses: buildings 1 and 6;
- Town houses or large apartments: buildings 2 and 7.

Number of bathrooms was not used as a comparison metric as it did not show any clear relationship with increased usage; further investigation on this is encouraged.

Table 5 Suite size and number of bathrooms for all buildings

Building	Suite metering	Average suite size, m^2	Number of suites	Number of bathrooms	Annual average, L/day/unit	Bathrooms/ suite ratio
Building 1	Yes, Hot water	69	126	186	303	1.48
Building 2	Yes, Hot water	81	77	139	546	1.81
Building 3	Yes, Hot & Cold water	75	72	140	356	1.94
Buildings 4 and 5	Yes, Hot & Cold water	80	107	196	643	1.83
Building 6	No	97	46	86	512	1.87
Building 7	No	113	11	15	740	1.36
Building 8	No	93	71	148	504	2.08
Building 9	No	77	60	100	694	1.67

From this analysis it was seen that less water consumption was achieved in the sub-metered buildings and also that the difference between the means was statistically significant on the three cases (separate variance t test $p<0.05$). More detailed information can be found on Appendix F of this report. However this method is subjective and showed some flaws because the buildings are not exactly the same. In addition, some buildings have low flow water fixtures and some others have standard ones. This becomes an issue when trying to allocate savings to sub-metering technology only. A larger sample size, further analysis and interpretation of results is necessary in order to distinguish which portion of the savings are actually due to the sub-metering technology and which portions should be attributed to other factors.

3.5.2 Individual Buildings Annual Consumption Averages

As a second option to evaluate the individual performance of the buildings, the annual consumption averages and variations obtained from UBC Utilities reports were assessed. Figure 14 outlines the four baseline buildings performance followed by the sub-metered buildings; seasonal variability experienced over the year is displayed as error bars. The timeframe for this analysis was also from September 2011 to August 2012, except for the case of buildings 4 and 5 that only had a few months of data at the time. The values that were used for these two buildings are indicative and do not take into consideration seasonal changes because all available readings were done over the summer months. For this reason, buildings 4 and 5 information was not used in further analysis.

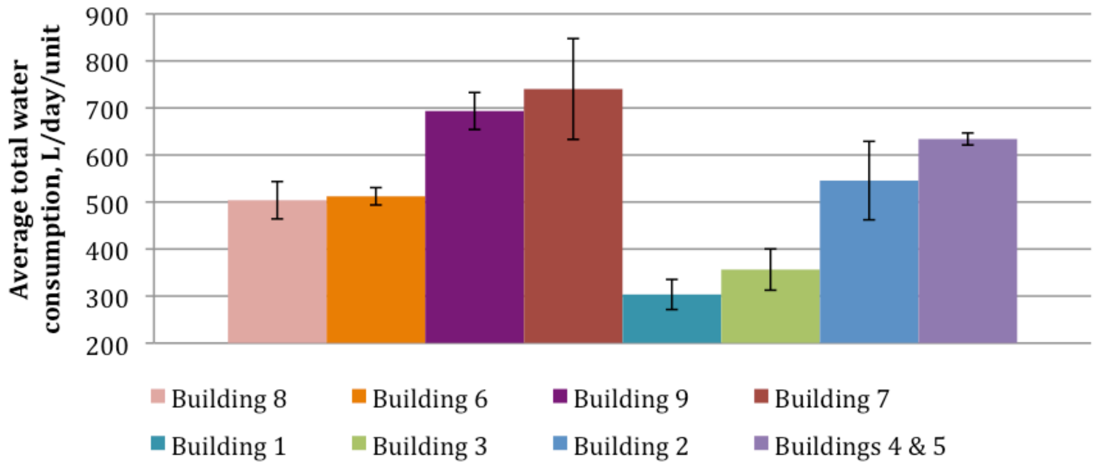

Figure 14 Annual total water consumption averages, Sep 2011-Aug 2012

All baselines building showed water usage patterns above 500 liters/day/unit. In general terms sub-metered buildings had lower values, however only building 1 and building 3 buildings were below the 500 liters/day/unit mark. At first instance Building 2 showed a much higher figure, but non-residential end uses were included in the readings. This fact represented a major issue and building 2 had to be taken out of the sample for further analysis in order to provide the best possible answer to the study's main question. The alternative comparison method consisted on evaluating edifices collectively and divided into two major groups: Bulk-metered buildings and Sub-metered buildings.

3.5.3 Bulk-metered v.s. Sub-metered buildings

This comparison method was based on obtaining monthly averages over the previously established period of time for the two groups, as shown in Figure 15. All baseline buildings were considered in the analysis in order to obtain the most accurate values, whereas this was not possible for the buildings with sub-metering. As mentioned on Section 3.5.2 buildings 4 and 5 did not had enough data to provide a realistic figure on what their consumption would be on a whole year basis and did not consider seasonal changes.

On the other hand, the buildings' high consumption readings from UBC Utilities are presumably including non-suite water features such as fountains. This is also the case of building 2, where the total water readings include a significant portion of non-residential water usage.

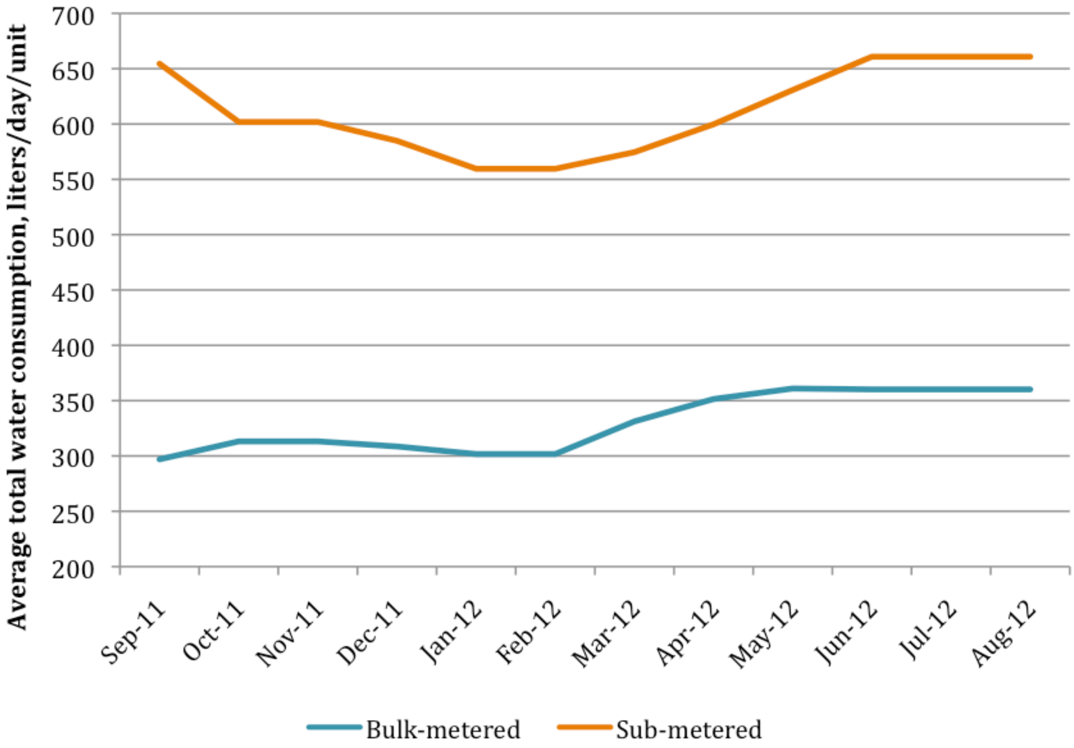

Figure 15 Bulk-metered vs. Sub-metered buildings comparison

Therefore only building 1 and building 3 data were used on the quantitative analysis for sub-metered buildings.

The bulk-metered buildings had an average consumption of 612 liters/day/unit (SD 122) while the sub-metered buildings (Building 1 and Building 3) had an average consumption of 330 liters/day/unit (SD 37). This difference was statistically significant (separate variance t test $p=0.015$). From Figure 15 it can be clearly seen that sub-metered buildings experienced a lower consumption rate throughout the evaluated period. In general terms, savings on total water consumption are being achieved in the buildings that have suite meters installed; this translates into average annual savings of 280 liters/day/unit of total water.

3.5.4 Benchmarking

The previous sections described the buildings' operation within UBC campus. However, it is also important to assess how well they act upon the provincial, national and international level. In order to assess the performance of the buildings involved in the study both bulk-metered and sub-metered water consumption per suite estimates had to be translated to daily per capita values.

Due to complications on gathering the data, actual numbers of people living in the buildings were not possible to obtain; alternatively estimates were done based on LEED guidelines to calculate occupancy taking into consideration the number of bedrooms (See Appendix F: Figure E 1). Water consumption averages for baseline buildings was rated at 225 liters/day/capita, while their sub-metered counterparts achieved a significantly lower 151 Liters/day/capita.

Figure 16 outlines that both bulk-metered and sub-metered buildings on campus perform better than the typical Canadian home. The most recent available estimated value is from 2009: 274 liters/day/capita, and way below the British Columbian average at 353 liters/day/capita (Environment Canada, 2011). The reductions achieved by the UNA sub-metered buildings on water use compared to the national and provincial levels are 45% and 57% respectively. However, Canada is one of the greatest water consumers in the world and compared with better performing countries like Belgium, 108 liters/day/capita, sub-metered buildings are nearer to close the gap (DEFRA, 2008).

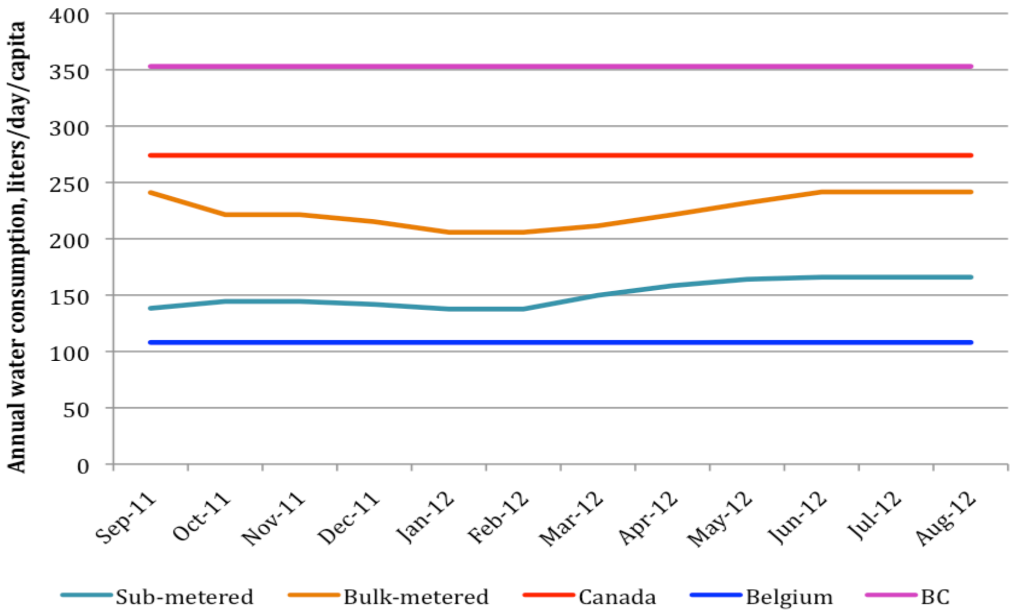

Figure 16 UNA buildings daily per capita averages in comparison with other jurisdictions

3.6 Performance of Sub-metered Buildings

The main focus of this study was to compare bulk-metering against sub-metering in UNA buildings, nevertheless a complementary analysis on the two different sub-metering schemes was conducted. The main difference between the two schemes lies on direct billing to tenants.

Hot water was selected as the point of comparison between the sub-metered buildings, because not all of them had cold water readings available. On the best case scenario at least one year of data should be obtained in order to make up for seasonal changes. Nevertheless in this case not all buildings fulfilled this requirement and some adjustments had to be made. Consequently hot water consumption per suite data were considered just for buildings 1, 2 and 3; buildings 4 and 5 only had a few months of data since they started operations on July 2012, and did not provide enough information to be considered in this part of the study. Due to the timing of the project, the covered period for this analysis was reduced to November 2011 to September 2012 because Building 3 only had 11 months of data. This had to be done also because sub-metering readings for Building 1 occur bimonthly and there was not enough time to get the October value. From Figure 17 it is possible to appreciate the consumption fluctuations throughout the period; values in all three of them are very similar. The averages for the three buildings were: building 1 at 129 liters/day/unit, building 2 at 131 liters/day/unit and building 3 at 130 liters/day/unit.

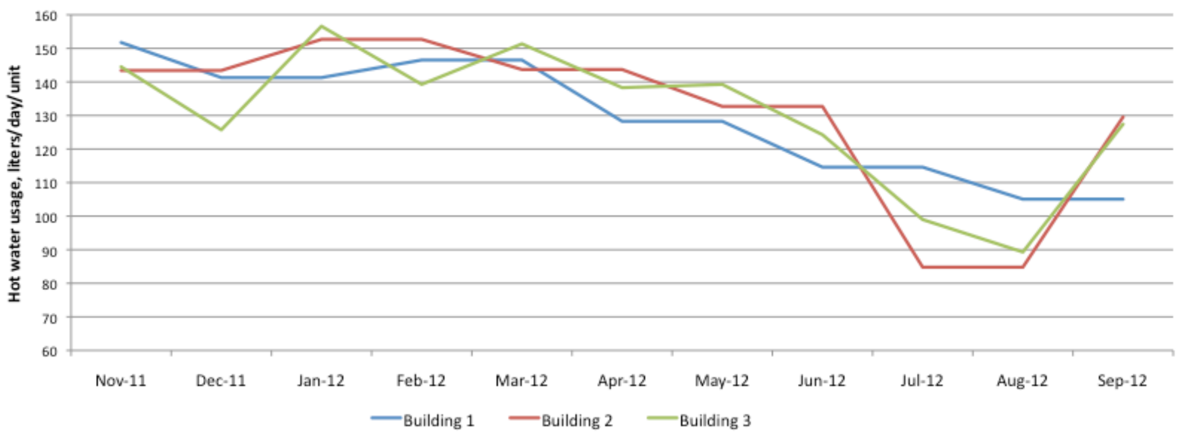

Figure 17 Hot water consumption analysis of suite-metered buildings

Further studies with more historical data available, could help clarify the impact of charging tenants directly (buildings 1 and 2) versus just informing of consumption (building 3). As far as this study can tell there are no relevant differences in annual consumption averages between them.

3.7 Gas and GHG Emissions

Due to the lack of information on hot water consumption for individual suites in baseline buildings, the potential reductions on hot water had to be approximated.
These values were based on the hot and cold water ratios for Building 3 and information on the Domestic Hot Water (DHW) systems. Taking this into consideration, natural gas and greenhouse gases (GHG) emissions were also calculated. From data on an average of 44% for hot and 56% for cold water was obtained and was used to calculate savings on natural gas consumption for water heating purposes.

Table 6 Hot and cold water usage for building 3, Nov 2011-Sep 2012		
Month	Cold water, %	Hot water, %
November, 2011	53%	47%
December, 2011	52%	48%
January, 2012	55%	45%
February, 2012	53%	47%
March, 2012	53%	47%
April, 2012	55%	45%
May, 2012	56%	44%
June, 2012	58%	42%
July, 2012	61%	39%
August, 2012	63%	37%
September, 2012	59%	41%
October, 2012	56%	44%

Bearing in mind the total water savings obtained in Section 3.5.3 Bulk-metered v.s. Sub-metered buildings (280 liters/day/unit) and the hot water portion of the total water readings, the potential hot water reductions were estimated at roughly 123 liters/day/unit. On a yearly basis for a 47 unit building (average number of suites for the baseline buildings) 2,110,000 liters could be saved. Translating these hot water savings into heating energy (output) and taking into account a raise in temperature of 90^{o} F, the resulting savings are 0.025 GJ/day/unit. On the input side the efficiency of the DHW boiler plays a significant role; actual commercial efficiency values (80 to 93%) for the DHW systems operating in the buildings were taken from the rated values shown in user manuals and mechanical schedules of record drawings. Using these figures as upper and lower limits the estimated average potential savings on natural gas supply for water heating are close to 0.03 GJ/day/unit or 10.95 GJ/year/unit. At the building level 515 GJ of thermal energy savings could be achieved, along with a 25.9 tonnes of CO_2 reduction per year. Calculations can be found in Appendix D: Savings calculations.

3.8 Uncertainty in Water Savings Estimates

During the development of the study at least five main factors that could contribute to uncertainty in the water savings for sub-metered buildings versus baseline buildings were identified. They can be listed as follows:

- Differences in irrigation: The irrigation portion contained in the total water readings from UBC Utilities varies greatly from one building to another; this impacts water savings directly and all related calculations. For example, if baseline buildings had a higher percentage of total water used for irrigation, this would inflate water savings. For the purpose of this study and due to lack of time, irrigations water was not separated from suite consumption.
- Efficiency of water fixtures: For the recently built edifices, datasets and other relevant information was provided by UBC Properties Trust and was possible to have a clear panorama of what kind of fixtures the buildings have in place. Nevertheless this was not the case for the older baseline buildings and very little detail is known about how efficient water-using appliances and fixtures are in sub-metered versus baseline buildings in the study. If sub-metered buildings have more efficient fixtures, then a fraction of the overall reductions in consumption could be due to the fixtures rather than the effect of sub-metering; future studies could help clarify this issue.
- Quantity of water-consuming fixtures: More fixtures could correlate to increased water usage. Quantifying the number of fixtures in the buildings could provide a better understanding of the relationship between the number of water outlets and the consumption level of tenants.
- Occupancy: Occupancy values obtained from UBC Properties Trust and described in this report refer to a percentage of units that were being rented during the time period of the study. However data on number and age of people actually occupying the suites was not available at the time this study was conducted; due to time limitations an accurate assessment of these figures was not pursued.
- Behavior of inhabitants: Data on how people operate their water fixtures was unavailable. Although it was not within the scope of this project, having a notion

of tenants' behavior such as choice of hot/warm/cold water settings on dishwashers and clothes washers, length of showers and frequency of clothes washing would have been beneficial for a more accurate estimation and understanding of the issue.

The five factors mentioned above, are interrelated and may be correlated; for example units with more bathrooms probably have more individuals per unit. Nonetheless these are all variables for which no data are available and which could be addressed in future studies.

3.9 Economic Perspective

The economic assessment of suite-metering technology was based on estimated capital costs of suite-metering technology and potential savings for both utilities: water and natural gas (see Appendix D for calculations) as follows:

- The average number of suites in the baseline buildings is 47. This number was taken into consideration for calculating annual potential savings;
- Meters and installation, with an estimated value of $670 per suite including equipment and nominal cost of installation, based on previous experience. This excludes additional services such as invoicing, record keeping, income statements and balance sheets, data collection and reporting or any other accounting activities;
- Water, taking into consideration water provision fees (at $0.03603/ft^2$ or $0.0012723/liter, according to UBC Utilities invoice) and sewage charges at 90% of total water sales. The economic savings due to avoided water fees are valued at $6,111 per year and the avoided sewage fees are calculated at $5,500 per year;
- Natural gas, based on natural gas cost at $9.85/GJ retrieved from Enerpro reports. In economical terms the savings are $5,073 per year;
- Carbon emissions, reductions in green house gases (GHG) also result in additional savings of around $650 per year accounting for carbon offsets, which are charged at $25 per ton of CO_2 in the province. However, this was not considered in the Net Present Value (NPV) of the project, as it is only applicable to faculty and staff buildings for which UBC is responsible. This does not apply to strata owned buildings and therefore would not be part of the financial business analysis for sub-metering.

With this information, the balance of the first year of the project shows a total initial investment of almost $32,000. On the other hand, the benefits achieved by the end of the opening year are roughly $16,500; the Payback Period (PBP) is approximately 1.9 years. In order to obtain the economical benefits for the whole life-cycle of the meters the NPV was estimated, assuming a discount rate of 10% along with a 10 years useful life of meters and equipment; it is summarized as NPV= -capital cost + gas savings + water savings + sewage savings.

$$NPV = -\left(\frac{\$670}{suite} \bullet 47 suites\right) + \$5{,}072 \bullet \left(\frac{1-(1+0.1)^{-10}}{0.1}\right) + \$6{,}111 \bullet \left(\frac{1-(1+0.1)^{-10}}{0.1}\right) + \$5{,}500 \bullet \left(\frac{1-(1+0.1)^{-10}}{0.1}\right)$$

$$NPV = \$71{,}028$$

Equation 1 Calculation of Net Present Value (NPV) of suite-metering project

From Equation 1 the total initial investment to retrofit the 47 units in the building would be $31,490, and the initial year savings result in: water savings of $37,552, sewage savings of $33,797 and gas savings of $31,170. Assuming that the current pricing maintains the same value during the following 10 years and no major maintenance is required, this results on life cycle savings of approximately $102,500 and a positive NPV of $71,028 during the whole useful life of the installed meters. This implies that suite metering is not just a means to reduce a building's carbon footprint and water consumption but might also be an economically feasible option. A deeper analysis on economics of suite-metering is encouraged on future studies; limitations on data and time prevented me from analyzing this on further detail, as it took generous amounts of time to estimate physical water savings in the first place. The cost of equipment and installation include most recent quote prices, but other previous projects have proven to be more costly and this directly impacts the whole calculation. Also, UBC Utilities manages two different rates for the buildings involved in this study: $\$0.03603/ft^2$ for UBC faculty and staff housing buildings (used in the calculations) and $\$0.02237/ft^2$ for market rental condominiums. The decision to use the former one was based on the notion that all baseline buildings potentially converting to suite metering, have these rates and because greater savings could be potentially achieved. Another aspect that is worth to be noted is that natural gas savings might be less than the ones reported depending on the efficiency of the DHW boiler or if the target building utilizes preheating from sustainable features, like geothermal or rejected heat systems as part of its water heating cycle. The nominal useful life of meters and related equipment is reported on a range of 10 to 15 years, however for the sake of this project the lower end was considered as a measure of accounting for contingency. The assumption was made that no other major piece of equipment such as boilers or pipes, was necessary to replace during the whole life cycle of the project.

4 Conclusion

While the national average of residential water use has experienced a decline, Canada is still among the highest water users in the world and more efforts are required on water conservation. Water is increasingly requiring a more efficient consumption rate from users. This is completely independent of its abundance within a community or country, not only to preserve it but also because activities involved in multiple stages of the supply chain such as treatment, distribution and heating also require the utilization of human and energy resources. This is where a sub-metering program has a goal as a tool to promote awareness in the multi-residential sector and encourage consumers to take over responsibility towards the environment. Within the scope of this study, it can be concluded that sub-metering has the potential of reducing water use, GHG emissions and gas consumption in buildings within the UNA.

In order to assess the feasibility of individual suite metering technology in UNA buildings, an environmental and economic analysis has been conducted on a small sample comprised of nine rental buildings within UBC's boundaries. The water use performance of baseline buildings was compared with that of sub-metered buildings, accounting for savings on total water, sewage costs, gas consumption and reductions on GHG emissions. The cost of implementing the system or capital cost was then compared to that of the potential savings throughout the useful life of the meters. For the purpose of the study all calculations of potential savings on water consumption, cost and emissions are based on actual data from UBC Utilities, UBC Properties Trust and Enerpro and recent estimates for pricing of meters, water and gas fees.

As illustrated in Section 3, when the status quo in control buildings (assuming 47 suites per building) is to be replaced with a sub-metering system, the total water savings are roughly 280 liters/day/unit; this translates to significant annual reductions in annual water consumption and sewage charges. From the estimated hot water fraction of that total (44%), gas consumption and related costs are forecasted to decline, while the equivalent carbon emissions are also expected to decrease annually. Accounting for all savings for an expected meters lifetime of 10 years, the project makes economical sense to developers, managers and tenants; the positive NPV and short payback period of the project is proof of it.

It is important to bear in mind that these results were obtained from a small-sized sample and should be corroborated with larger ones in the future. Furthermore, if residential water use can be isolated to obtain more accurate data that could give a clearer panorama on the topic. In addition all water savings were assumed to be due to sub-metering. In the future, accounting for other factors contributing to lower water consumption like water fixtures and number of inhabitants is encouraged. Also economic values can vary in real terms because assumptions were made on some steps of the calculations. For example all water heating is assumed to come from burning gas and the cost of meters and utilities are taken for granted to stay fixed during the 10-year period.

However, this is still a positive finding and promising initial step for future research opportunities. In conclusion, if the sub-metering system is to replace the actual bulk-metering scheme, there is a good probability that they will help on the efforts on fostering a more efficient use of water in UNA buildings by increasing awareness on tenants.

5 Recommendations

Upon completion of this project, it is recommended that the following aspects be taken into consideration for further work:

- **Conduct an assessment on a larger sample of buildings, including both on campus and off campus edifices with a minimum of one year of data.** It was good to have a complete set of data for most of the buildings in the samples. However, this was not the case for all of them and they do not represent all the residential buildings on campus. If more REAP certified buildings on campus could be studied that would provide a more accurate representation; data for more buildings is needed and should be collected within UBC campus. It would also be beneficial to study buildings outside the boundaries of UBC, both with and without sub-metering technology installed.
- **Conduct an assessment on the impact of billing tenants for their consumption versus only informing them of their usage in sub-metered**

suites. The small amount of data on this topic and the short time for the project prevented a deeper analysis on the different sub-metering schemes and their benefits and trade-offs. It is recommended that this be considered in future studies and when more data is available.

- **Conduct a detailed analysis on end uses of total water of selected buildings.** Unfortunately utility bills and meter readings that were the primary source of data on total consumption are not broken down by end-use and there was no practical or easy way to obtain this information within the timeframe constraints. Nevertheless cold water meters in Granite Terrace dedicated to measuring other non-residential water uses like irrigation and fountains are in place and can help determine the amount of non-residential water on the total water meter readings. Due to the meters recent installation, I was prevented from gathering as much data as needed to make a proper analysis since this project was scheduled to be finished in a relatively short period of time.
- **Study a sample of suites from a baseline building with no sub-metering installed to have an estimate on the hot water portion consumed in the dwellings.** In addition it is suggested that for future studies a temporary means of measuring hot water consumption (i.e. hot water gauge) in bulk-metered buildings be installed on random suites. This approach will enable a more accurate measurement of hot water usage and will help establish a baseline for control buildings.
- **Analyze actual gas consumption bills of the buildings and the contribution of sustainable DHW heating features on reducing natural gas usage for water heating purposes.** For a more detailed analysis of energy requirements for water heating, additional information would be needed concerning the allocation of natural gas to other end-uses, such as space heating and home appliances. The calculated gas consumption and savings can ideally be compared with actual ones, for this specific project there was not enough time to do so. It would also be favorable to study buildings that have energy efficient technologies in place such as geothermal heat pumps or waste heat recovery systems.
- **Assess inhabitants' behavior towards water conservation and acceptance of sub-metering technology.** The main purpose of water meters is to make people aware of their actual water usage and promote a positive change in inhabitants'

behavior towards water conservation. Hence, a survey can be conducted to assess psychological factors, their impact on the success of implementing the technology and the willingness to pay water fees directly.

- **Conduct a policy analysis on sub-metering and water conservation measures.** Although it is outside the scope of this study, policy is a major instrument which affects water consumption patterns and would be interesting to analyze successful cases and how they could be implemented locally. High water consumption in Canada could be attributed to the lack of widespread water conservation practices. Another factor could be water pricing that in some cases is less than the actual cost of processing and distributing the resource. Policy tools could be created to foster an economic incentive or promote more efficient practices.

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"Gratitude is when memory is stored in the heart and not in the mind."-Lionel Hampton

APPENDIX A

Buildings characteristics and
Total water consumption data

Table A 2 Monthly total water average consumption for building 2, UBC Utilities

Building	Month	Days	Average Daily consumption, m^3/day/building	Total monthly consumption, m^3/building	Average Daily consumption, L/day/building	Average Daily consumption per unit, L/day/unit
Building 2	Apr-09	30	1.52	46	1,517	19.70
77	May-09	31	8.72	270	8,724	113.30
Number of units	Jun-09	30	19.18	575	19,176	249.04
	Jul-09	31	19.18	594	19,176	249.04
	Aug-09	31	89.44	2,773	89,445	1,161.62
	Sep-09	30	138.43	4,153	138,427	1,797.76
	Oct-09	31	113.09	3,506	113,086	1,468.65
	Nov-09	30	113.09	3,393	113,086	1,468.65
	Dec-09	31	156.66	4,856	156,657	2,034.50
	Jan-10	31	216.99	6,727	216,985	2,817.99
	Feb-10	28	216.99	6,076	216,985	2,817.99
	Mar-10	31	140.18	4,346	140,182	1,820.55
	Apr-10	30	44.10	1,323	44,099	572.72
	May-10	31	57.39	1,779	57,394	745.38
	Jun-10	30	76.44	2,293	76,436	992.67
	Jul-10	31	76.44	2,370	76,436	992.67
	Aug-10	31	76.44	2,370	76,436	992.67
	Sep-10	30	60.15	1,805	60,153	781.21
	Oct-10	31	41.54	1,288	41,544	539.53
	Nov-10	30	41.54	1,246	41,544	539.53
	Dec-10	31	36.64	1,136	36,645	475.91
	Jan-11	31	32.05	994	32,052	416.26
	Feb-11	28	32.05	897	32,052	416.26
	Mar-11	31	35.94	1,114	35,938	466.73
	Apr-11	30	44.10	1,323	44,099	572.72
	May-11	31	48.77	1,512	48,767	633.34
	Jun-11	30	57.25	1,718	57,253	743.55
	Jul-11	31	57.25	1,775	57,253	743.55
	Aug-11	31	57.25	1,775	57,253	743.55
	Sep-11	30	48.41	1,452	48,411	628.71
	Oct-11	31	33.14	1,027	33,138	430.36
	Nov-11	30	33.14	994	33,138	430.36
	Dec-11	31	35.22	1,092	35,220	457.41
	Jan-12	31	40.31	1,250	40,311	523.51
	Feb-12	29	40.31	1,169	40,311	523.51
	Mar-12	31	40.24	1,247	40,236	522.55
	Apr-12	30	40.08	1,202	40,080	520.52
	May-12	31	42.99	1,333	42,989	558.30
	Jun-12	30	50.10	1,503	50,100	650.65
	Jul-12	31	50.10	1,553	50,100	650.65
	Aug-12	31	50.10	1,553	50,100	650.65
		MIN	**1.52**	**46**	**1,517**	**19.70**
		MAX	**216.99**	**6,727**	**216,985**	**2,817.99**
		AVE	**63.73**	**1,937**	**63,730**	**827.66**
		MED	**48.41**	**1,452**	**48,411**	**628.71**

Table A 3 Monthly total water average consumption for Building 1, UBC Utilities

Building	Month	Days	Average Daily consumption, m^3/day/building	Total monthly consumption, m^3/building	Average Daily consumption, L/day/building	Average Daily consumption per unit, L/day/unit
Building 1	Jun-09	30	25.99	779.72	25,991	199.93
126	Jul-09	31	25.99	805.71	25,991	199.93
Number of units	Aug-09	31	25.99	805.71	25,991	199.93
	Sep-09	30	33.34	1,000.29	33,343	256.48
	Oct-09	31	44.37	1,375.53	44,372	341.32
	Nov-09	30	44.37	1,331.15	44,372	341.32
	Dec-09	31	41.49	1,286.22	41,491	319.16
	Jan-10	31	35.44	1,098.69	35,441	272.63
	Feb-10	28	35.44	992.36	35,441	272.63
	Mar-10	31	36.95	1,145.38	36,948	284.21
	Apr-10	30	38.78	1,163.31	38,777	298.29
	May-10	31	42.71	1,323.96	42,708	328.53
	Jun-10	30	48.93	1,467.98	48,933	376.41
	Jul-10	31	48.93	1,516.91	48,933	376.41
	Aug-10	31	48.93	1,516.91	48,933	376.41
	Sep-10	30	45.33	1,359.81	45,327	348.67
	Oct-10	31	41.21	1,277.38	41,206	316.97
	Nov-10	30	41.21	1,236.18	41,206	316.97
	Dec-10	31	38.98	1,208.42	38,981	299.86
	Jan-11	31	36.28	1,124.69	36,280	279.08
	Feb-11	28	36.28	1,015.85	36,280	279.08
	Mar-11	31	39.12	1,212.65	39,118	300.91
	Apr-11	30	36.05	1,081.38	36,046	277.28
	May-11	31	38.50	1,193.61	38,504	296.18
	Jun-11	30	42.39	1,271.83	42,394	326.11
	Jul-11	31	42.39	1,314.23	42,394	326.11
	Aug-11	31	42.39	1,314.23	42,394	326.11
	Sep-11	30	41.03	1,230.91	41,030	315.62
	Oct-11	31	39.67	1,229.65	39,666	305.12
	Nov-11	30	39.67	1,189.99	39,666	305.12
	Dec-11	31	37.85	1,173.24	37,846	291.13
	Jan-12	31	34.54	1,070.67	34,538	265.68
	Feb-12	29	34.54	1,001.60	34,538	265.68
	Mar-12	31	34.89	1,081.63	34,891	268.39
	Apr-12	30	35.53	1,066.02	35,534	273.34
	May-12	31	39.92	1,237.59	39,922	307.10
	Jun-12	30	45.25	1,357.54	45,251	348.09
	Jul-12	31	45.25	1,402.79	45,251	348.09
	Aug-12	31	45.25	1,402.79	45,251	348.09
		MIN	**25.99**	**780**	**25,991**	**199.93**
		MAX	**48.93**	**1,517**	**48,933**	**376.41**
		AVE	**39.26**	**1,197**	**39,261**	**302.01**
		MED	**39.67**	**1,213**	**39,666**	**305.12**

Table A 4 Monthly total water average consumption for building 3, UBC Utilities

Building	Month	Days	Average Daily consumption, m^3/day/building	Total monthly consumption, m^3/building	Average Daily consumption, L/day/building	Average Daily consumption per unit, L/day/unit
Building 3	Mar-11	31	4.62	143.21	4,620	64.16
72	Apr-11	30	4.62	138.59	4,620	64.16
Number of units	May-11	31	9.45	293.09	9,455	131.31
	Jun-11	30	18.25	547.37	18,246	253.41
	Jul-11	31	18.25	565.61	18,246	253.41
	Aug-11	31	18.25	565.61	18,246	253.41
	Sep-11	30	20.04	601.07	20,036	278.27
	Oct-11	31	23.13	716.95	23,127	321.21
	Nov-11	30	23.13	693.82	23,127	321.21
	Dec-11	31	23.47	727.69	23,474	326.03
	Jan-12	31	24.32	753.94	24,321	337.79
	Feb-12	29	24.32	705.30	24,321	337.79
	Mar-12	31	28.37	879.52	28,372	394.05
	Apr-12	30	30.93	927.90	30,930	429.58
	May-12	31	29.86	925.77	29,864	414.77
	Jun-12	30	26.80	803.94	26,798	372.19
	Jul-12	31	26.80	830.74	26,798	372.19
	Aug-12	31	26.80	830.74	26,798	372.19
		MIN	**4.62**	**139**	**4,620**	**64.16**
		MAX	**30.93**	**928**	**30,930**	**429.58**
		AVE	**21.19**	**647**	**21,189**	**294.29**
		MED	**23.30**	**711**	**23,301**	**323.62**

Table A 5 Monthly total water average consumption for Building 6, UBC Utilities

Building	Month	Days	Average Daily consumption, m^3/day/building	Total monthly consumption, m^3/building	Average Daily consumption, L/day/building	Average Daily consumption per unit, L/day/unit
Building 6	Jan-10	31	17.97	557.09	17,971	399.35
45	Feb-10	28	17.97	503.18	17,971	399.35
Number of units	Mar-10	31	18.45	571.95	18,450	410.00
	Apr-10	30	19.83	594.82	19,827	440.61
	May-10	31	21.80	675.71	21,797	484.38
	Jun-10	30	25.38	761.34	25,378	563.95
	Jul-10	31	25.38	786.71	25,378	563.95
	Aug-10	31	25.38	786.71	25,378	563.95
	Sep-10	30	22.54	676.30	22,543	500.97
	Oct-10	31	19.30	598.43	19,304	428.98
	Nov-10	30	19.30	579.13	19,304	428.98
	Dec-10	31	19.53	605.49	19,532	434.04
	Jan-11	31	19.81	614.06	19,808	440.19
	Feb-11	28	19.81	554.63	19,808	440.19
	Mar-11	31	19.70	610.55	19,695	437.67
	Apr-11	30	19.46	583.72	19,457	432.39
	May-11	31	21.72	673.38	21,722	482.71
	Jun-11	30	25.31	759.24	25,308	562.40
	Jul-11	31	25.31	784.55	25,308	562.40
	Aug-11	31	25.31	784.55	25,308	562.40
	Sep-11	30	24.63	738.76	24,625	547.23
	Oct-11	31	23.84	739.19	23,845	529.89
	Nov-11	30	23.84	715.35	23,845	529.89
	Dec-11	31	23.32	722.89	23,319	518.20
	Jan-12	31	22.03	683.04	22,033	489.63
	Feb-12	29	22.03	638.97	22,033	489.63
	Mar-12	31	22.14	686.33	22,140	491.99
	Apr-12	30	22.33	669.98	22,333	496.28
	May-12	31	22.60	700.75	22,605	502.33
	Jun-12	30	23.27	698.08	23,269	517.10
	Jul-12	31	23.27	721.35	23,269	517.10
	Aug-12	31	23.27	721.35	23,269	517.10
		MIN	**17.97**	**503**	**17,971**	**399.35**
		MAX	**25.38**	**787**	**25,378**	**563.95**
		AVE	**22.06**	**672**	**22,057**	**490.16**
		MED	**22.24**	**680**	**22,236**	**494.14**

Table A 6 Monthly total water average consumption for building 8, UBC Utilities

Building	Month	Days	Average Daily consumption, m^3/day/building	Total monthly consumption, m^3/building	Average Daily consumption, L/day/building	Average Daily consumption per unit, L/day/unit
Building 8	Feb-07	28	17.00	476.00	17,000	239.44
71	Mar-07	31	17.00	527.00	17,000	239.44
Number of units	Apr-07	30	17.00	510.00	17,000	239.44
	May-07	31	17.00	527.00	17,000	239.44
	Jun-07	30	28.99	869.70	28,990	408.31
	Jul-07	31	28.99	898.69	28,990	408.31
	Aug-07	31	28.99	898.69	28,990	408.31
	Sep-07	30	24.41	732.19	24,406	343.75
	Oct-07	31	20.40	632.40	20,400	287.32
	Nov-07	30	20.40	612.00	20,400	287.32
	Dec-07	31	22.74	704.81	22,736	320.22
	Jan-08	31	26.20	812.20	26,200	369.01
	Feb-08	29	26.20	759.80	26,200	369.01
	Mar-08	31	27.41	849.83	27,414	386.11
	Apr-08	30	27.70	831.00	27,700	390.14
	May-08	31	31.62	980.35	31,624	445.41
	Jun-08	30	35.81	1,074.30	35,810	504.37
	Jul-08	31	35.81	1,110.11	35,810	504.37
	Aug-08	31	35.81	1,110.11	35,810	504.37
	Sep-08	30	32.93	987.98	32,933	463.84
	Oct-08	31	29.18	904.58	29,180	410.99
	Nov-08	30	29.18	875.40	29,180	410.99
	Dec-08	31	28.09	870.75	28,089	395.61
	Jan-09	31	26.77	829.87	26,770	377.04
	Feb-09	28	26.77	749.56	26,770	377.04
	Mar-09	31	28.25	875.85	28,253	397.93
	Apr-09	30	30.31	909.30	30,310	426.90
	May-09	31	31.04	962.17	31,038	437.15
	Jun-09	30	34.08	1,022.40	34,080	480.00
	Jul-09	31	34.08	1,056.48	34,080	480.00
	Aug-09	31	34.08	1,056.48	34,080	480.00
	Sep-09	30	32.36	970.88	32,363	455.81
	Oct-09	31	29.79	923.49	29,790	419.58
	Nov-09	30	29.79	893.70	29,790	419.58
	Dec-09	31	29.40	911.50	29,403	414.13
	Jan-10	31	28.87	894.97	28,870	406.62
	Feb-10	28	28.87	808.36	28,870	406.62
	Mar-10	31	29.16	903.81	29,155	410.64
	Apr-10	30	29.56	886.80	29,560	416.34
	May-10	31	30.78	954.10	30,777	433.48
	Jun-10	30	33.00	990.00	33,000	464.79
	Jul-10	31	33.00	1,023.00	33,000	464.79
	Aug-10	31	33.00	1,023.00	33,000	464.79
	Sep-10	30	31.84	955.13	31,838	448.42
	Oct-10	31	30.32	939.92	30,320	427.04
	Nov-10	30	30.32	909.60	30,320	427.04
	Dec-10	31	29.03	899.82	29,027	408.82
	Jan-11	31	26.68	827.08	26,680	375.77

	Feb-11	28	26.68	747.04	26,680	375.77
	Mar-11	31	28.57	885.72	28,572	402.42
	Apr-11	30	32.02	960.60	32,020	450.99
	May-11	31	35.11	1,088.35	35,108	494.48
	Jun-11	30	40.73	1,221.90	40,730	573.66
	Jul-11	31	40.73	1,262.63	40,730	573.66
	Aug-11	31	40.73	1,262.63	40,730	573.66
	Sep-11	30	37.34	1,120.18	37,339	525.90
	Oct-11	31	33.46	1,037.26	33,460	471.27
	Nov-11	30	33.46	1,003.80	33,460	471.27
	Dec-11	31	33.40	1,035.39	33,400	470.42
	Jan-12	31	33.24	1,030.44	33,240	468.17
	Feb-12	29	33.24	963.96	33,240	468.17
	Mar-12	31	33.75	1,046.26	33,750	475.36
	Apr-12	30	35.21	1,056.30	35,210	495.92
	May-12	31	36.42	1,128.89	36,416	512.90
	Jun-12	30	39.89	1,196.82	39,894	561.89
	Jul-12	31	39.89	1,236.72	39,894	561.89
	Aug-12	31	39.89	1,236.72	39,894	561.89
		MIN	**17.00**	**476**	**17,000**	**239.44**
		MAX	**40.73**	**1,263**	**40,730**	**573.66**
		AVE	**30.50**	**929**	**30,504**	**429.63**
		MED	**30.32**	**923**	**30,320**	**427.04**

Table A 7 Monthly total water average consumption for building 7, UBC Utilities

Building	Month	Days	Average Daily consumption, m^3/day/building	Total monthly consumption, m^3/building	Average Daily consumption, L/day/building	Average Daily consumption per unit, L/day/unit
Building 7	Jul-01	31	13.00	403.00	13,000	1,181.82
11	Aug-01	31	13.00	403.00	13,000	1,181.82
Number of units	Sep-01	30	13.00	390.00	13,000	1,181.82
	Oct-01	31	7.62	236.22	7,620	692.73
	Nov-01	30	7.62	228.60	7,620	692.73
	Dec-01	31	7.29	225.96	7,289	662.65
	Jan-02	31	6.14	190.34	6,140	558.18
	Feb-02	28	6.14	171.92	6,140	558.18
	Mar-02	31	6.39	198.11	6,391	580.98
	Apr-02	30	7.42	222.60	7,420	674.55
	May-02	31	7.42	230.02	7,420	674.55
	Jun-02	30	7.94	238.20	7,940	721.83
	Jul-02	31	10.52	326.12	10,520	956.36
	Aug-02	31	10.52	326.12	10,520	956.36
	Sep-02	30	10.33	310.01	10,334	939.43
	Oct-02	31	9.40	291.40	9,400	854.55
	Nov-02	30	9.40	282.00	9,400	854.55
	Dec-02	31	9.16	284.01	9,162	832.87
	Jan-03	31	8.74	270.94	8,740	794.55
	Feb-03	28	8.74	244.72	8,740	794.55
	Mar-03	31	8.73	270.54	8,727	793.38
	Apr-03	30	8.69	260.70	8,690	790.00
	May-03	31	8.69	269.39	8,690	790.00
	Jun-03	30	10.03	300.80	10,027	911.53
	Jul-03	31	11.05	342.55	11,050	1,004.55
	Aug-03	31	11.05	342.55	11,050	1,004.55
	Sep-03	30	10.30	309.10	10,303	936.66
	Oct-03	31	9.01	279.31	9,010	819.09
	Nov-03	30	9.01	270.30	9,010	819.09
	Dec-03	31	7.12	220.70	7,119	647.21
	Jan-04	31	6.08	188.48	6,080	552.73
	Feb-04	29	6.08	176.32	6,080	552.73
	Mar-04	31	7.36	228.01	7,355	668.66
	Apr-04	30	10.48	314.40	10,480	952.73
	May-04	31	10.48	324.88	10,480	952.73
	Jun-04	30	12.42	372.65	12,422	1,129.25
	Jul-04	31	14.64	453.84	14,640	1,330.91
	Aug-04	31	14.64	453.84	14,640	1,330.91
	Sep-04	30	12.21	366.41	12,214	1,110.33
	Oct-04	31	9.03	279.93	9,030	820.91
	Nov-04	30	9.03	270.90	9,030	820.91
	Dec-04	31	7.83	242.72	7,830	711.78
	Jan-05	31	6.96	215.76	6,960	632.73
	Feb-05	28	6.96	194.88	6,960	632.73
	Mar-05	31	8.38	259.73	8,378	761.68
	Apr-05	30	11.85	355.50	11,850	1,077.27
	May-05	31	11.85	367.35	11,850	1,077.27
	Jun-05	30	11.99	359.62	11,987	1,089.76

Jul-05	31	13.96	432.76	13,960	1,269.09
Aug-05	31	13.96	432.76	13,960	1,269.09
Sep-05	30	13.59	407.70	13,590	1,235.44
Oct-05	31	8.46	262.26	8,460	769.09
Nov-05	30	8.46	253.80	8,460	769.09
Dec-05	31	7.57	234.52	7,565	687.76
Jan-06	31	7.20	223.20	7,200	654.55
Feb-06	28	7.20	201.60	7,200	654.55
Mar-06	31	7.45	231.10	7,455	677.70
Apr-06	30	8.33	249.90	8,330	757.27
May-06	31	8.49	263.22	8,491	771.91
Jun-06	30	13.38	401.40	13,380	1,216.36
Jul-06	31	13.38	414.78	13,380	1,216.36
Aug-06	31	13.38	414.78	13,380	1,216.36
Sep-06	30	11.74	352.13	11,738	1,067.05
Oct-06	31	8.45	261.95	8,450	768.18
Nov-06	30	8.45	253.50	8,450	768.18
Dec-06	31	7.02	217.53	7,017	637.92
Jan-07	29	5.98	173.42	5,980	543.64
Feb-07	28	5.98	167.44	5,980	543.64
Mar-07	31	6.42	198.98	6,419	583.52
Apr-07	30	9.38	281.40	9,380	852.73
May-07	31	9.36	290.07	9,357	850.65
Jun-07	30	8.82	264.60	8,820	801.82
Jul-07	31	8.82	273.42	8,820	801.82
Aug-07	31	8.82	273.42	8,820	801.82
Sep-07	30	10.28	308.29	10,276	934.23
Oct-07	31	17.55	544.05	17,550	1,595.45
Nov-07	30	17.55	526.50	17,550	1,595.45
Dec-07	31	19.51	604.77	19,509	1,773.51
Jan-08	31	21.12	654.72	21,120	1,920.00
Feb-08	29	21.12	612.48	21,120	1,920.00
Mar-08	31	13.88	430.21	13,878	1,261.61
Apr-08	30	12.48	374.40	12,480	1,134.55
May-08	31	11.46	355.35	11,463	1,042.09
Jun-08	30	10.98	329.40	10,980	998.18
Jul-08	31	10.98	340.38	10,980	998.18
Aug-08	31	10.98	340.38	10,980	998.18
Sep-08	30	11.20	335.93	11,198	1,017.98
Oct-08	31	11.42	354.02	11,420	1,038.18
Nov-08	30	11.42	342.60	11,420	1,038.18
Dec-08	31	9.59	297.36	9,592	872.01
Jan-09	31	7.37	228.47	7,370	670.00
Feb-09	28	7.37	206.36	7,370	670.00
Mar-09	31	7.74	239.92	7,739	703.59
Apr-09	30	8.25	247.50	8,250	750.00
May-09	31	9.09	281.93	9,094	826.77
Jun-09	30	11.17	335.10	11,170	1,015.45
Jul-09	31	11.17	346.27	11,170	1,015.45
Aug-09	31	11.17	346.27	11,170	1,015.45
Sep-09	30	9.84	295.29	9,843	894.82
Oct-09	31	7.17	222.27	7,170	651.82
Nov-09	30	7.17	215.10	7,170	651.82

	Dec-09	31	7.70	238.72	7,701	700.05
	Jan-10	31	7.17	222.27	7,170	651.82
	Feb-10	28	7.17	200.76	7,170	651.82
	Mar-10	31	7.13	221.01	7,129	648.13
	Apr-10	30	7.08	212.40	7,080	643.64
	May-10	31	8.12	251.60	8,116	737.83
	Jun-10	30	9.37	281.10	9,370	851.82
	Jul-10	31	9.37	290.47	9,370	851.82
	Aug-10	31	9.37	290.47	9,370	851.82
	Sep-10	30	7.19	215.74	7,191	653.76
	Oct-10	31	5.01	155.31	5,010	455.45
	Nov-10	30	5.01	150.30	5,010	455.45
	Dec-10	31	7.50	232.64	7,505	682.23
	Jan-11	31	9.84	305.04	9,840	894.55
	Feb-11	28	9.84	275.52	9,840	894.55
	Mar-11	31	8.54	264.75	8,540	776.38
	Apr-11	30	7.47	224.10	7,470	679.09
	May-11	31	8.33	258.36	8,334	757.64
	Jun-11	30	9.76	292.80	9,760	887.27
	Jul-11	31	9.76	302.56	9,760	887.27
	Aug-11	30	9.76	292.80	9,760	887.27
	Sep-11	31	8.43	261.34	8,430	766.38
	Oct-11	31	7.67	237.77	7,670	697.27
	Nov-11	30	7.67	230.10	7,670	697.27
	Dec-11	31	7.26	225.20	7,264	660.40
	Jan-12	31	6.93	214.83	6,930	630.00
	Feb-12	29	6.93	200.97	6,930	630.00
	Mar-12	31	7.17	222.13	7,165	651.40
	Apr-12	30	7.33	219.90	7,330	666.36
	May-12	31	8.65	268.29	8,655	786.78
	Jun-12	30	9.89	296.80	9,893	899.40
	Jul-12	31	9.89	306.70	9,893	899.40
	Aug-12	31	9.89	306.70	9,893	899.40
		MIN	**5.01**	**150**	**5,010**	**455.45**
		MAX	**21.12**	**655**	**21,120**	**1,920.00**
		AVE	**9.57**	**292**	**9,572**	**870.23**
		MED	**8.92**	**272**	**8,915**	**810.45**

Table A 8 Monthly total water average consumption for building 9, UBC Utilities

Building	Month	Days	Average Daily consumption, m^3/day/building	Total monthly consumption, m^3/building	Average Daily consumption, L/day/building	Average Daily consumption per unit, L/day/unit
Building 9	Jan-05	31	29.01	899.31	29,010	483.50
60	Feb-05	28	29.01	812.28	29,010	483.50
Number of units	Mar-05	31	29.04	900.20	29,039	483.98
	Apr-05	30	29.14	874.20	29,140	485.67
	May-05	31	29.14	903.34	29,140	485.67
	Jun-05	30	31.13	933.96	31,132	518.87
	Jul-05	31	49.09	1,521.79	49,090	818.17
	Aug-05	31	49.09	1,521.79	49,090	818.17
	Sep-05	30	49.09	1,472.70	49,090	818.17
	Oct-05	31	49.09	1,521.79	49,090	818.17
	Nov-05	30	49.09	1,472.70	49,090	818.17
	Dec-05	31	41.99	1,301.63	41,988	699.80
	Jan-06	31	37.50	1,162.50	37,500	625.00
	Feb-06	28	37.50	1,050.00	37,500	625.00
	Mar-06	31	37.26	1,154.97	37,257	620.95
	Apr-06	30	29.98	899.40	29,980	499.67
	May-06	31	31.29	970.13	31,294	521.57
	Jun-06	30	50.31	1,509.30	50,310	838.50
	Jul-06	31	50.31	1,559.61	50,310	838.50
	Aug-06	31	50.31	1,559.61	50,310	838.50
	Sep-06	30	50.52	1,515.60	50,520	842.00
	Oct-06	31	51.57	1,598.67	51,570	859.50
	Nov-06	30	51.57	1,547.10	51,570	859.50
	Dec-06	31	43.48	1,347.81	43,478	724.63
	Jan-07	29	37.63	1,091.27	37,630	627.17
	Feb-07	28	37.63	1,053.64	37,630	627.17
	Mar-07	31	39.69	1,230.49	39,693	661.56
	Apr-07	30	53.59	1,607.70	53,590	893.17
	May-07	31	53.74	1,665.93	53,740	895.66
	Jun-07	30	58.13	1,743.90	58,130	968.83
	Jul-07	31	58.13	1,802.03	58,130	968.83
	Aug-07	31	58.13	1,802.03	58,130	968.83
	Sep-07	30	62.85	1,885.36	62,845	1,047.42
	Oct-07	31	86.40	2,678.40	86,400	1,440.00
	Nov-07	30	86.40	2,592.00	86,400	1,440.00
	Dec-07	31	66.71	2,068.07	66,712	1,111.87
	Jan-08	31	50.50	1,565.50	50,500	841.67
	Feb-08	29	50.50	1,464.50	50,500	841.67
	Mar-08	31	41.44	1,284.54	41,437	690.61
	Apr-08	30	39.69	1,190.70	39,690	661.50
	May-08	31	45.95	1,424.56	45,953	765.89
	Jun-08	30	52.63	1,578.90	52,630	877.17
	Jul-08	31	52.63	1,631.53	52,630	877.17
	Aug-08	31	52.63	1,631.53	52,630	877.17
	Sep-08	30	50.47	1,514.12	50,471	841.18
	Oct-08	31	48.31	1,497.61	48,310	805.17
	Nov-08	30	48.31	1,449.30	48,310	805.17
	Dec-08	31	46.72	1,448.36	46,721	778.69

	Jan-09	31	44.79	1,388.49	44,790	746.50
	Feb-09	28	44.79	1,254.12	44,790	746.50
	Mar-09	31	45.20	1,401.22	45,201	753.35
	Apr-09	30	45.77	1,373.10	45,770	762.83
	May-09	31	48.15	1,492.68	48,151	802.52
	Jun-09	30	53.97	1,619.10	53,970	899.50
	Jul-09	31	53.97	1,673.07	53,970	899.50
	Aug-09	31	53.97	1,673.07	53,970	899.50
	Sep-09	30	50.91	1,527.36	50,912	848.53
	Oct-09	31	46.32	1,435.92	46,320	772.00
	Nov-09	30	46.32	1,389.60	46,320	772.00
	Dec-09	31	47.21	1,463.42	47,207	786.79
	Jan-10	31	50.25	1,557.75	50,250	837.50
	Feb-10	28	50.25	1,407.00	50,250	837.50
	Mar-10	31	49.64	1,538.75	49,637	827.28
	Apr-10	30	48.89	1,466.70	48,890	814.83
	May-10	31	51.93	1,609.74	51,927	865.45
	Jun-10	30	57.45	1,723.50	57,450	957.50
	Jul-10	31	57.45	1,780.95	57,450	957.50
	Aug-10	31	57.45	1,780.95	57,450	957.50
	Sep-10	30	50.95	1,528.57	50,952	849.21
	Oct-10	31	42.46	1,316.26	42,460	707.67
	Nov-10	30	42.46	1,273.80	42,460	707.67
	Dec-10	31	42.34	1,312.52	42,339	705.66
	Jan-11	31	42.13	1,306.03	42,130	702.17
	Feb-11	28	42.13	1,179.64	42,130	702.17
	Mar-11	31	41.96	1,300.85	41,963	699.38
	Apr-11	30	41.77	1,253.10	41,770	696.17
	May-11	31	45.84	1,421.16	45,844	764.06
	Jun-11	30	53.26	1,597.80	53,260	887.67
	Jul-11	31	53.26	1,651.06	53,260	887.67
	Aug-11	30	53.26	1,597.80	53,260	887.67
	Sep-11	31	46.70	1,447.73	46,701	778.35
	Oct-11	31	42.54	1,318.74	42,540	709.00
	Nov-11	30	42.54	1,276.20	42,540	709.00
	Dec-11	31	41.41	1,283.57	41,406	690.09
	Jan-12	31	39.02	1,209.62	39,020	650.33
	Feb-12	29	39.02	1,131.58	39,020	650.33
	Mar-12	31	40.77	1,263.73	40,765	679.42
	Apr-12	30	44.43	1,332.90	44,430	740.50
	May-12	31	43.26	1,340.99	43,258	720.96
	Jun-12	30	39.89	1,196.82	39,894	664.90
	Jul-12	31	39.89	1,236.72	39,894	664.90
	Aug-12	31	39.89	1,236.72	39,894	664.90
		MIN	**29.01**	**812**	**29,010**	**483.50**
		MAX	**86.40**	**2,678**	**86,400**	**1,440.00**
		AVE	**46.96**	**1,429**	**46,959**	**782.64**
		MED	**46.96**	**1,448**	**46,964**	**782.74**

Table A 9 Monthly total water average consumption for buildings 4 and 5, UBC Utilities

Building	Month	Days	Average Daily consumption, m^3/day/building	Total monthly consumption, m^3/building	Average Daily consumption, L/day/building	Average Daily consumption per unit, L/day/unit
Buildings 4 & 5	Jun-12	30	9.30	279.00	9,300	86.91
107	Jul-12	31	66.88	2,073.27	66,880	625.04
Number of units	Aug-12	31	68.80	2,132.77	68,799	642.98
		MIN	**9.30**	**279**	**9,300**	**86.91**
		MAX	**68.80**	**2,133**	**68,799**	**642.98**
		AVE	**48.33**	**1,495**	**48,326**	**451.65**
		MED	**66.88**	**2,073**	**66,880**	**625.04**

APPENDIX B

Hot water consumption data

Table B 1 Complete water dataset for building 3					
Month	Average Cold Water, L/day/unit	Average Hot Water, L/day/unit	Cold+Hot Water QMC, L/day/unit	Average Total Water UBC Utilities, L/day/unit	Occupancy, %
Sep-11				278.27	97%
Oct-11				321.21	100%
Nov-11	163.707	144.513	308.22	321.21	99%
Dec-11	135.151	125.728	260.88	326.03	100%
Jan-12	188.110	156.595	344.71	337.79	97%
Feb-12	159.923	139.273	299.20	337.79	97%
Mar-12	171.931	151.343	323.27	394.05	99%
Apr-12	172.389	138.301	310.69	429.58	100%
May-12	180.408	139.272	319.68	414.77	97%
Jun-12	171.586	124.260	295.85	372.19	99%
Jul-12	153.996	98.985	252.98	372.19	89%
Aug-12	152.021	89.302	241.32	372.19	92%
AVERAGE	**164.922**	**130.757**	**295.680**	**356.441**	**97%**
MEDIAN	**167.646**	**138.786**	**303.708**	**321.214**	**98%**
MAX	**188.110**	**156.595**	**344.706**	**429.583**	**100%**
MIN	**135.151**	**89.302**	**241.324**	**278.272**	**89%**

Table B 2 Complete data set for building 2			
Month	Average Hot Water, L/day/unit	Average Total Water, L/day/unit	Occupancy, %
Sep-11	134.52	628.71	100%
Oct-11	134.52	430.36	100%
Nov-11	143.41	430.36	97%
Dec-11	143.41	457.41	95%
Jan-12	152.69	523.51	96%
Feb-12	152.69	523.51	94%
Mar-12	143.70	522.55	92%
Apr-12	143.70	520.52	95%
May-12	132.70	558.30	94%
Jun-12	132.70	650.65	94%
Jul-12	84.80	650.65	95%
Aug-12	84.80	650.65	96%
AVERAGE	**131.969**	**545.599**	**96%**
MEDIAN	**138.964**	**523.513**	**95%**
MAX	**152.691**	**650.649**	**100%**
MIN	**84.798**	**430.363**	**92%**

Table B 3 Complete data set for building 1			
Month	Average Hot Water, L/day/unit	Average Total Water, L/day/unit	Occupancy, %
May-11	141.17	296.18	77%
Jun-11	116.90	326.11	69%
Jul-11	116.90	326.11	79%
Aug-11	119.73	326.11	91%
Sep-11	119.73	315.62	95%
Oct-11	151.76	305.12	98%
Nov-11	151.76	305.12	98%
Dec-11	141.29	291.13	99%
Jan-12	141.29	265.68	98%
Feb-12	146.53	265.68	94%
Mar-12	146.53	268.39	95%
Apr-12	128.27	273.34	98%
May-12	128.27	307.10	97%
Jun-12	114.60	348.09	99%
Jul-12	114.60	348.09	91%
Aug-12	105.06	348.09	99%
AVERAGE	**132.473**	**303.453**	**97%**
MEDIAN	**134.780**	**305.125**	**98%**
MAX	**151.757**	**348.087**	**99%**
MIN	**105.060**	**265.676**	**91%**

Table B 4 Complete dataset for buildings 4 & 5 (assuming 100% occupancy rates)				
Month	Average Cold Water, L/day/unit	Average Hot Water, L/day/unit	Cold+Hot Water QMC, L/day/unit	Average Total Water UBC U, L/day/unit
Jul-12	185.79	94.26	280.05	625.04
Aug-12	171.28	131.13	302.40	642.98
Sep-12	184.81	134.65	319.46	571.56
Oct-12	188.52	146.56	335.08	509.07
AVERAGE	**178.532**	**137.445**	**291.225**	**634.013**
MEDIAN	**178.532**	**112.693**	**291.225**	**634.013**
MAX	**185.785**	**131.125**	**302.404**	**642.982**
MIN	**171.279**	**94.260**	**280.045**	**509.065**

APPENDIX C

Domestic Hot Water (DHW)
Systems and Water Fixtures

Table C 1 Domestic Hot Water (DHW) Systems

Building	Rated Input, BTUH	Rated Output, BTUH	Actual Thermal efficiency, %
Building 1	250,000	226,000	90
Building 2	399,000	322,790	81
Building 3	399,000	319,200	80
Building 4	399,00	374,237	93
Building 5	399,000	374,237	93
Building 6	199,999	185,999	93
Building 7	412,000	329,600	80
Building 8	650,000	552,500	85
Building 9	645,000	527,500	85

Table C 2 Water fixtures and appliances

Fixture detail	Building 1	Building 2	Building 3	Building 4	Building 5	Building 6	Building 7	Building 8	Building 9
Standard-flush toilets (6L/flush)									
Low-flush or dual low-flush toilets (4L/flush, 6 & 3 L/flush)	X		X	X	X	X			
Low-flow faucet aerators in bathroom sinks (3.8 L/min)	X		X			X		X	
Low-flow faucet aerators in kitchen sinks (6.8 L/min)	X		X			X		X	
Low-flow faucet aerators in bathroom sinks (8.3 L/min)				X	X				
Low-flow faucet aerators in kitchen sinks (8.3 L/min)				X	X				
Standard-flow shower heads (max flow rate of 9.5 L/min)							X	X	X
Low-flow shower heads (max flow rate of 5.7 L/min)	X	X	X			X			
Low-flow shower heads (max flow rate of 4.4 L/min @ 60 psi)				X	X				
Water efficient dishwashers (less than 20 L/normal cycle)	X		X			X			
Water efficient clothes washer (max water consumption of 62 L/cycle)	X		X			X			
Hot water suite metering	X		X	X	X				
Cold water suite metering			X	X	X				
Heat recovery (50% efficient system)	X	X	X						
Geoexchange DHW heating system (25% peak DHW heating load & 70% total DHW energy load	X	X							
Gas suite metering									
Gas DHW boiler (min efficiency of 85%) or electric DSW (energy factor of 0.94)	X		X						
Gas DHW boiler (min efficiency of 92%) or electric DSW (energy factor of 1.00)				X	X	X			
Gas fireplaces							X		
In-Suite Electric Baseboard Heaters		X					X	X	X
RESULT	**Efficient**	**Efficient**	**Efficient**	**Efficient**	**Efficient**	**Efficient**	**Standard**	**Standard**	**Standard**

* For buildings 7 and 9 there was no available data on fixtures, but the property manager said they are older buildings that have no low flow fixtures and were pre-REAP certification.

$$hotwateruse = 280L/day/unit \bullet (.44) \approx 123L/day/unit$$

APPENDIX D

Savings calculations

$$hotwateruse = 123L/day/unit \bullet 47units \bullet 365days$$
$$hotwateruse = 2{,}110{,}065L/year/building$$

$$gas_{DHW} = 123L/day/unit \bullet \left(3.185\frac{USgal}{L}\right) \bullet \left(8.33\frac{lb}{USgal}\right) \bullet 90°F$$

$$gas_{DHW} = 24,365BTU/day/unit$$

$$gas_{input80\%eff} = \left(\frac{24,365BTU/day/unit}{.8}\right) \bullet \left(1,055.0559x10^{-9}\frac{GJ}{BTU}\right) = .03213GJ/day/unit$$

$$gas_{input93\%eff} = \left(\frac{24,365BTU/day/unit}{.93}\right) \bullet \left(1,055.0559x10^{-9}\frac{GJ}{BTU}\right) = .02764GJ/day/unit$$

The above figures result on an average gas input of .03 GJ/day/unit and an average gas output of 0.025 GJ/day/unit; therefore the annual savings are:

$$Savings = 0.03GJ/day/unit \bullet 365days/year$$

$$Savings = 10.95GJ/unit/year$$

Assuming that a building with 47 suites (average number of suites for baseline buildings) could potentially have meters installed the savings result in:

$$Savings = 0.03GJ/day/unit \bullet 365days \bullet 47units$$

$$Savings \approx 515GJ/year$$

$$Savings = 515GJ \bullet \left(\frac{\$9.85}{GJ}\right)$$

$$Savings = \$5,072.75$$ (per year)

$$GHG_{savings} = 515GJ \bullet .0505\frac{tonnesofCO_2}{GJ}$$

$$GHG_{savings} = 25.9tonnesofCO_2$$

$$GHG_{savings} = 25.9tonnesofCO_2 \bullet \left(\frac{\$25}{tonneofCO_2}\right)$$ This is only valid for Faculty and Staff buildings

$$GHG_{savings} = \$647.50/year$$

$$NPV = -\left(\frac{\$670}{suite} \bullet 47suites\right) + \$5,072.75 \bullet \left(\frac{1-(1+0.1)^{-10}}{0.1}\right) + \$6,111.36 \bullet \left(\frac{1-(1+0.1)^{-10}}{0.1}\right) + \$5,500.22 \bullet \left(\frac{1-(1+0.1)^{-10}}{0.1}\right)$$

$$NPV = \$71,028.08$$

Additional calculations confirming values on gas and GHG reductions

Hot water thermal energy savings: E = mass * Cp * ΔT and ΔT = 90 °F / 1.8 = 50 °C
123 L/unit-day * 365 day/yr * m^3/1000 L * 1000 kg/m^3 * 50 °C * 4.18x10^{-6} GJ/kg-°C = 9.38 GJ/unit-yr

Natural gas savings (assume average boiler & distribution efficiency of 85%):

9.38 GJ/unit-yr / 0.85 * 50.3 kg CO_2/GJ = 555 kg CO_2/unit-yr or 26.08 tonnes of CO_2/year for a 47 unit building.

APPENDIX E

Water Consumption per Capita and Benchmarking

Figure E 1 SNIP from LEED document on estimating occupancy

Pre-approved ID: Bicycle Storage

Maximum *Points: 2*

Note: These points should be counted on the checklist within ID credit 3.

Intent

Reduce pollution and land development impacts from automobile use.

Requirements

Prerequisites (Mandatory Measures)

N/A

Credits (Optional Measures)

Bicycle Storage. (2 Points) Provide secure, covered storage facilities for 15% or more of the building occupants. Guidelines for estimating occupancy are provided in Exhibit A below.

Exhibit A.
Guidelines for Estimating Occupancy

Unit type	Estimated occupancy
Studio	1
1-bedroom	1.5
2-bedroom	2.5
3-bedroom	3.5
4-bedroom	4.5
5-bedroom	5.5

Table E 1 Average monthly consumption for all buildings, liters/day/capita

Month	Consumption @Building 8, L/day/capita	Consumption @Building 6, L/day/capita	Consumption @Building 9, L/day/unit	Consumption @Building 7, L/day/capita	Consumption @Building 1, L/day/capita	Consumption @Building 3, L/day/capita
Sep-11	189.06	185.15	322.08	267.63	162.82	113.84
Oct-11	169.42	179.28	293.38	243.49	157.41	131.41
Nov-11	169.42	179.28	293.38	243.49	157.41	131.41
Dec-11	169.11	175.33	285.56	230.61	150.18	133.37
Jan-12	168.30	165.67	269.10	220.00	137.05	138.19
Feb-12	168.30	165.67	269.10	220.00	137.05	138.19
Mar-12	170.89	166.46	281.14	227.47	138.46	161.20
Apr-12	178.28	167.92	306.41	232.70	141.01	175.74
May-12	184.38	169.96	298.33	274.75	158.42	169.68
Jun-12	202.00	174.96	275.13	314.08	179.57	152.26
Jul-12	202.00	174.96	275.13	314.08	179.57	152.26
Aug-12	202.00	174.96	275.13	314.08	179.57	152.26
Average	**181.10**	**173.30**	**286.99**	**258.53**	**156.54**	**145.82**
SD	14.27	6.24	16.28	37.46	16.52	17.93

Table E 2 Annual averages comparison between jurisdictions

Month	Monthly averages Metered bldgs, L/day/unit	Monthly averages Non-metered bldgs, L/day/unit	Canadian average	Belgium average	BC average
Sep-11	138.33	240.98	274	108	353
Oct-11	144.41	221.39	274	108	353
Nov-11	144.41	221.39	274	108	353
Dec-11	141.78	215.15	274	108	353
Jan-12	137.62	205.77	274	108	353
Feb-12	137.62	205.77	274	108	353
Mar-12	149.83	211.49	274	108	353
Apr-12	158.37	221.33	274	108	353
May-12	164.05	231.86	274	108	353
Jun-12	165.91	241.54	274	108	353
Jul-12	165.91	241.54	274	108	353
Aug-12	165.91	241.54	274	108	353
Average	**151**	**225**	**274**	**108**	**353**
Savings		**33%**	**45%**	**-40%**	**57%**

APPENDIX F

Statistical Analysis

Table F 1 T-test for two samples: Bulk-metered buildings vs. Suite-metered buildings

A two-sample T-test was conducted using Systat V.10 to analyze the two main groups involved in the study: Group M (buildings that have sub-metered technology installed: Sub-metered) and Group N (no individual suites installed: Bulk-metered).

Two-sample t test on WC grouped by BT$

Group	Number of buildings	Mean	SD
Sub-metered	2	329.947	37.468
Bulk-metered	4	612.462	122.202

Separate Variance t = -4.242
df = 3.8
Prob = 0.015
Difference in Means = -282.515 95.00%
CI = -470.739 to -94.290

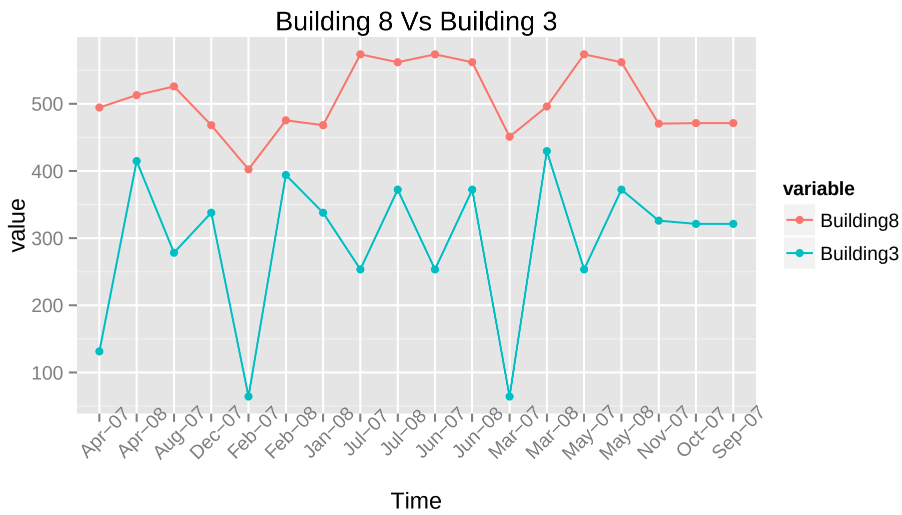
Pooled Variance t = -3.035
df = 4
Prob = 0.039
Difference in Means = -282.515 95.00%
CI = -540.936 to -24.093

Brief Report

Yunlong

November 13, 2012

1 Buiding 8 vs Building 3



Simple T-test is applied to test whether the mean of Building 8 is greater than the mean of Building 3. Let μ_8 and μ_3 stands for the mean of Building 8 and 3 respectively. The null hypothsis will be

$$\mu_8 = \mu_3,$$

and the alternative hypothsis will be

$$\mu_8 > \mu_3$$

.

If the p-value of the test is less than 0.05, we reject null hypothsis ($\mu_8 = \mu_3$) and claim that $\mu_8 > \mu_3$, otherwise we cannot reject null hypothsis.

Before carring out t-test, it is necessary to know that the assumpsions t-test make.

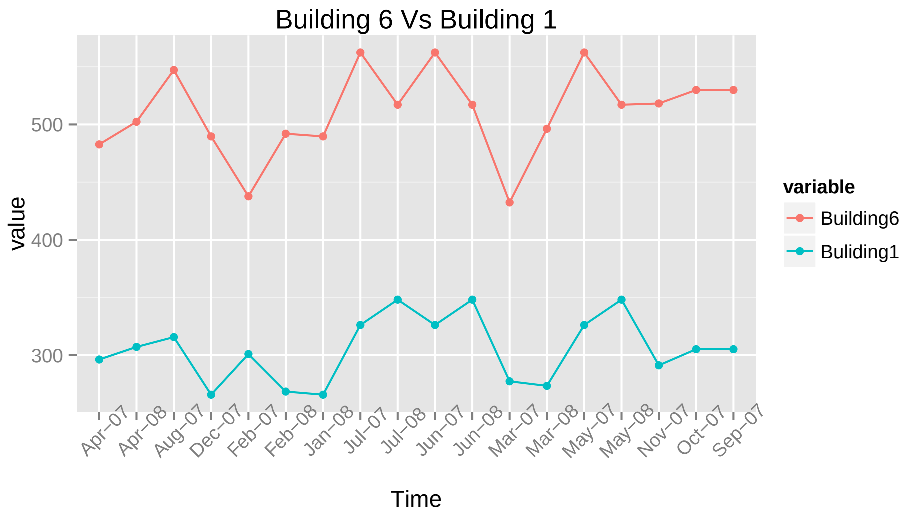
- two samples are from normal populations
- two samples are from two normal populations with equal variance.
- observations in each sample are independent.

We will first F test whether the variances of two samples are equal. If equal variance is not rejected, we then perform simple two-sample t-test, otherwise another t-test, which called Welch t-test will be applied.

1.1 results

- the p-value for equal variance assumption is 0.003 $<$ 0.05, which means it is not that reasonable the assume equal variance for the two samples.
- Performing Welch two-sample t-test, the p-value is 1.13e-07, which means the mean of Building 8 is significantly different than Building 3.

2 Buiding 6 vs Building 1

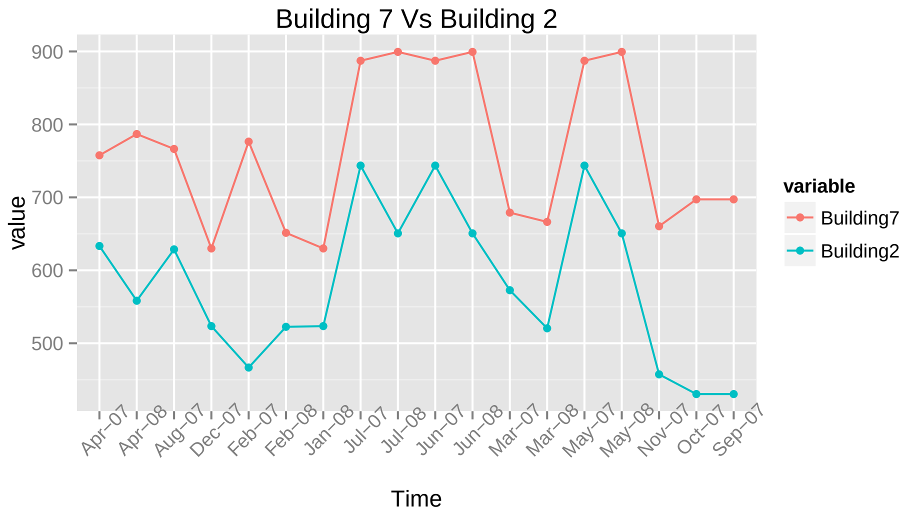


Same procedure discussed before and the results are as below:

2.1 results

- the p-value for equal variance assumption is 0.24 $>$ 0.05, which means it is fine the assume equal variance for the two samples.
- Performing simple two-sample t-test, the p-value is 2.4e-19 $<$ 0.05, which means the mean of Building 6 is significantly different than Building 1.

3 Buiding 7 vs Building 2



Same procedure discussed before and the results are as below:

3.1 results

- the p-value for equal variance assumption is $0.99 > 0.05$, which means it is fine the assume equal variance for the two samples.
- Performing simple two-sample t-test, the p-value is 7.809e-06 < 0.05, which means the mean of Building 7 is significantly different than Building 2.

4 Summary

	Comparison	P-value	lower	upper	equal variance
1	Building6 Vs Buliding1	2.4e-19	182.6	227.6	TRUE
2	Building7 Vs Building2	7.8e-06	112.8	254.7	TRUE
3	Building8 Vs Building3	1.1e-07	153.0	271.0	FALSE