UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Measurement & Analysis of Energy-Saving Optimization Systems for Vending Machines

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CEEN 596

January 7th, 2013

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CEEN 596 Project Report

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Acknowledgements

I take this opportunity to express my great appreciation and regards to Ms. Lillian Zaremba of UBC Sustainability for her exemplary guidance, support and provision of valuable information, which helped me in completing this task through its various stages.

I also take this opportunity to express a deep sense of gratitude to Dr. Eric Mazzi, Teaching Fellow of the Master of Engineering in Clean Energy Program, for his advice, assistance and monitoring my project progress.

I give special thanks to Ms. Victoria Wakefield of UBC Student Housing & Hospitality Services for her time and assistance with coordination, communications and valuable support with logistics.

I am obliged to Ms. Alicia Munro of Library Finance and Facilities for arranging and providing me with the necessary furniture which assisted in the issuing of my surveys and also my friend, Stefan Khan-Kernahan for his advice and assisting me with the purchasing of vending machine products.

My grateful thanks are also extended to Ms. Brenda Sawada of UBC SEEDS for her support and encouragement, as well as Mr. Clark Lundeen of Green College, the initial inspiration behind the project idea.

I wish to also acknowledge the help and information provided on the vending machines by Mr. John Lotto of Coca Cola and the technical support and information provided by the Watts Up? Meter manufacturer.

Lastly, I thank the higher universal powers, my parents, sister and friends for their encouragement, without which this assignment would not have been possible.

Kiran Harnanan

1.0 Executive Summary

The purpose of this report was to examine the functionality of load managing devices in the form of vending misers and snack misers and quantify any energy savings which could be achieved if there is full implementation of these devices on the UBC campus vending machines. Three types of machines were evaluated: a conventional chilled beverage vending machine, an Energy Star rated chilled beverage vending machine and an unrefrigerated snack machine. A watt-meter was used to gather baseline data on power and energy while an IR thermometer was used to obtain temperature readings. Thereafter, the VM-170 and SM-170 misers were installed on the vending and snack machines respectively. Surveys were issued to customers and post-miser installation data was obtained followed by data evaluation and comparative analysis on the two sets of data. It was found that the load managing devices saved 41.0%, 9.7% and 43.1% of energy on a conventional chilled beverage vending machine, an Energy Star rated chilled beverage vending machine and an unrefrigerated snack machine respectively.

Based on the above percentages and payback period after a cost-benefit analysis, it was determined that the best suitable machines for misers in a full scale analysis, were conventional machines which had estimated cost savings of $73.77/year, energy savings of 126,264kWh/year and a payback period of 3.3 years (without rebate). It was found, as well, that although the average temperature of chilled beverages rose by 0.6°C, 65.7% of survey respondents were unable to distinguish a change in temperature. Through behavioural assessment, there was no need for a customer educational campaign relating to how vending machines work with vending misers since devices did not power down the machines until after closing hours when there was no occupancy.

2.0 Introduction

The University of British Columbia (UBC) is widely recognized and known for its efforts towards being a sustainable campus. However there are always areas which have potential room for improvement when it comes to energy savings and cost cutting. One such area which this pilot project will attempt to assess, is that of vending machines and their energy consumption and whether or not it can be reduced cost effectively by the implementation of vending/energy misers. Vending misers are devices that manage the operation of lighting and cooling in vending machines to cut energy use by up to fifty percent [1]. There are approximately 111 operational vending machines and 88 snack machines on the UBC campus which are managed by Student Housing and Hospitality Services (SHHS). The vending machines typically demand between 300W-500W and are thought to consume about 600,000kWh electricity per year. Saving quarter of this energy with the use of vending misers would be equivalent to shutting down a small building.

3.0 Purpose

The purpose of this pilot project is to assess the operation and performance of load managing devices in the form of vending misers and snack misers and determine whether energy savings can be achieved if there is full implementation of these devices on campus vending machines. Furthermore it will also assess the behaviour of customers and their interaction with vending/snack machines after installation of the load managing devices, which make use of sensor occupancy detection. However, there are concerns from machine vendors as customers tend to avoid machines with misers installed since they appear to be off or non-functional. Appropriate signage or an educational campaign could remedy this misconception.

This project is being undertaken because there is potential for energy savings from the vending and snack machines on the UBC campus. When combined, the approximately 199 vending machines and snack machines on campus can consume a significant amount of power each year. The installation of load managing devices such as vending misers, have the potential to save not only on energy consumption of these vending machines, but also on UBC's electricity bill as well as its greenhouse gas emissions.

4.0 Objectives

The objectives of this project are defined as follows:

- Identify the environment and most suitable type of vending and snack miser that will be used in the pilot study.
- Determine and compare the baseline power consumption with load managing power consumption.
- Record and compare vending machine product temperature with and without load managing power consumption.
- Observe customer behaviour and conduct post installation surveys of the vending and snack misers on their respective machines.
- Perform a cost benefit analysis of vending and snack miser installation by quantifying and comparing the costs and benefits.
- Estimate the energy and cost savings along with potential reduction of CO_2 equivalent gases, given full scale implementation of these vending/energy misers.

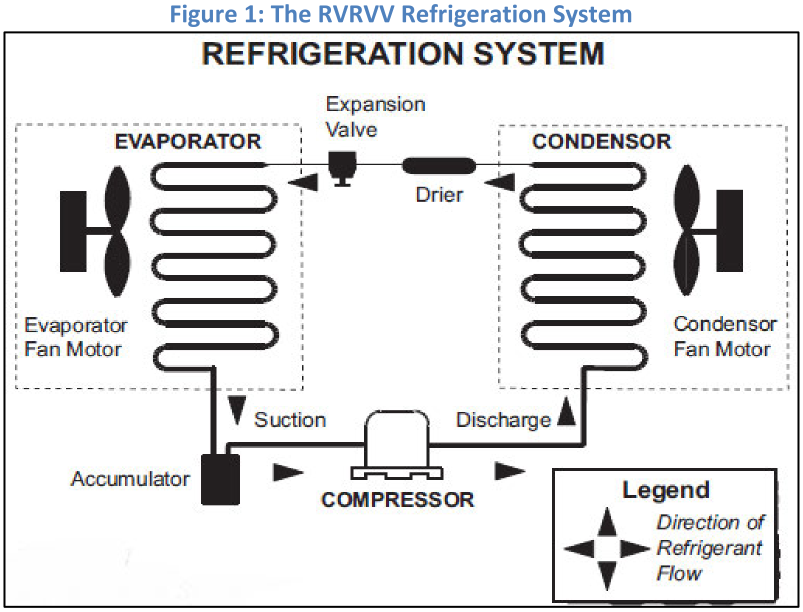
Recommendations will then be made depending on the findings of this pilot project.

5.0 Background

5.1 Vending Machine Operation

Vending machines are self-contained plug-in devices which have dispensing systems and money changing systems, controlled by complex electronic circuits and sensors [1]. The refrigeration system of a typical vending machine comprises about 65% of the energy use with its mechanical and electrical operation compared to the remaining 35% of the rest of systems housed in the machine, namely lighting and money control mechanisms[2]. Beverages in the vending machine have to be maintained at a temperature above 0°C and usually not more than 4.4°C. A conventional vending machine refrigeration system comprises of a compressor, a condenser fan and motor, an expansion valve, evaporator fan and motor as seen in Figure 1. The diagram shows how the layout of the refrigeration system in a typical vending machine works.

Figure 1: The RVRVV Refrigeration System



(Source: RVV NG /RVV NG PLUS Operation and Service Manual)

The refrigeration system operates in the following fashion[3][4]:

1. When the temperature sensor detects an increase in temperature, it is relayed to the control board which compares the temperature to a pre-programmed setting. If the temperature detected is greater than or equal to the pre-programmed temperature, the control board will send signals to impart energy to the refrigeration relay coil.

2. The refrigeration relay coil will close the contact to complete the circuit and thus allows 115 volts to start the compressor which will circulate the refrigerant R134a through the coils by sucking the low pressure R134a from the evaporator coils.

3. The refrigerant is then compressed and sent to the condenser which makes use of a fan that removes the heat from the high-pressure refrigerant vapour as it flows through the condenser tubes, condensing it into a high pressure liquid and then allowing the heat to dissipate into the environment.

4. The expansion valve then creates low pressure and vaporizes the refrigerant as it absorbs heat evaporated as it is passed through the evaporator in the cooling coils.

5. The continuous removal of heat during the compressor cycle reduces the temperature of the cooling section in the vending machine.

6. When the sensor detects that the temperature falls below the pre-programmed temperature, the control board breaks the refrigeration relay connection, thus shutting off the refrigeration system.

The accumulator stores any refrigerant which did not vaporize on its way to the compressor and the drier traps moisture in the system.

One of the chilled beverage vending machines which were the subject of this investigation was Energy Star rated. Energy Star is a trusted and government-backed symbol for energy efficiency which helps to reduce costs and environmental damage via energy efficient products and practices. Vending machines which qualify for this rating are those new and refurbished machines which have more efficient compressors, fan motors, insulation and lighting systems to keep its beverages the same temperature as expected, but use less energy (up to 50% less) while doing so. These types of machines are usually capable of entering a low power mode state when the machine is user-inactive for a certain period of time[5].

5.2 Snack Machine Operation

The snack machine under investigation was not temperature controlled but instead made the use of a fan and motor to dehumidify the air and prevent the buildup of moisture on the snack machine products. The glass front panel and inner casing of the snack machine are usually insulated. The metal helical spirals which dispense the items are controlled by a motor which turns the spirals by a certain amount to dispense a particular snack from the unrefrigerated machine[6].

At the bottom of the snack machine, a line of laser beams determines if your product has been released by the metal spirals. Each laser beam is paired with an electronic light sensor. When your product falls it breaks this path, telling the computer that it was a successful transaction.

5.3 Vending & Snack Misers

It has been claimed that vending misers reduce maintenance costs of the vending machine by reducing the number of compressor cycles as well as lengthening the duration of each cycle for the machine. A typical compressor cycle for a vending machine varies between 10 minutes to 15 minutes and occurs about 3 to 4 times per hour. The vending miser controls and extends the compressor cycle so that it varies between 20 minutes to 30 minutes, which occurs 1 to 2 times every two hours. Most vending misers and snack misers control the lighting system when the machine is powered down. Even though power cycling fluorescent lamps shorten their hourly lifetime, manufacturers claim that vending misers can increase the life of fluorescent lamps inside the vending machines as the power-down times of the machines are longer than the continuous hours of lamp lighting[7]. Vending misers have been tested by various vending machine manufacturers, including Dixie-Narco, one of the main manufacturers located in the United States. The findings with respect to the functionality of vending misers have been claimed to be replicated by these companies.

Vending misers can be divided into two main types: internal and external. Internal vending misers use sales-based programming to shut off the cooling system when occupancy levels are low. Sales forecasting programming are effective in reducing the energy needed to cool the products in a vending machine by predicting sales volume and cooling only the minimum number of items in the machine[8].

An example of this type is the VM2iQ model which is installed inside the vending machine and thus hidden from sight as there are no external components. It monitors the room's temperature and re-powers the compressor at regular intervals to maintain desired chilled temperature of products. This type of miser is best suited for vending machines with card readers which are located in high traffic areas such as airports and around the clock convenience stores. In this system, the compressor and evaporator fan operations are controlled but the lights stay on all the time[9].

External vending misers, which this project will incorporate and investigate, are devices that consist of two main parts, the miser itself and a passive infra-red motion sensor which is either mounted on the machine or affixed to the wall. The PIR sensor system monitors occupancy and the external room temperature and will relate these inputs to the vending miser which will control the powering up and down of the machine. The standard setting of 15 minutes of non-occupancy will power down the compressor and re-power it at regularly timed 2 hour intervals to maintain desired product temperature. External vending misers are best suited for low traffic areas with regular patterns and durations of non-occupancy[10].

The power cord of the vending machine is plugged into the miser and the power cord of the miser is plugged into the wall outlet[11]. When the sensor does not detect any motion, the miser will instruct the machine to be powered down, given that the compressor is not running. If the compressor is running there would be a time delay for the power down sequence. The miser is designed as such that it monitors the external temperature of the room and allows the vending machine to come on every few hours (1hr -3hrs depending on the type of machine) even if the sensor is not activated by any movement. This ensures that the contents such as beverages and certain snacks stay at the desired temperature regardless of proximal occupancy. The vending miser does not affect the internal thermostat or the operation of the compressor[12].

6.0 Literature Review

6.1 Energy Saving Studies

There are not many published studies focused on load managing devices for vending and snack machines as these are practical devices, however the following cases have made mention of them. In September 2011, The University of Louisiana estimated the energy consumption for each of its buildings and those estimates revealed that the university was wasting a significant amount of energy. In their analysis, one of the recommendations that were made was to implement the use of vending misers on the campus' vending machines. The devices were installed on all 'cool-drink' vending machines on campus and the estimated annual savings were found to be $30,000/year. The simple payback period, which is defined as the cost to make the change/energy cost savings per year, was estimated to be 0.5 years[13].

The Kuwait Institute for Scientific Research (KISR) audited the institute's main building in 2004 after it was thought that the efforts made to reduce the energy consumption of the building were minimal and more focused on the lighting savings. It was found that energy savings could be obtained from the closure of the one vending machine located in the building's cafeteria. KISR decided that by closing one of the cafeteria's vending machine on a Wednesday between the hours of 3:00pm to midnight and on weekends, the estimated annual energy savings were calculated to be 5000kWh/year[14].

The Texas A&M University completed an extensive evaluation of vending misers and the percentage of energy expected to be saved under various settings and with different vending machine models. It was found that power reduction could range from 48% to 65% depending on the settings of the misers[15]. The Harvard University Office for Sustainability embarked on a project in May 2012 where 20 vending and snack misers were installed on the machines at the Harvard Law School. It is predicted that these devices will save 3.4 metric tons of CO_2 equivalents and $1440/year[16]. Massachusetts Institute of Technology (MIT) - Department of Facilities, installed 30 vending misers in 2002 and the project showed a 46% reduction in energy consumption by these machines which cost-translated to approximately $4200/year.

6.2 Behavioural Studies

With respect to the behaviour of people and customers' interaction with vending machines, there have been some studies published, but these are limited in number and content as this is more of a practical problem that is tackled with trial and error implementations. In a study published in the Journal of School Health, it was found that out of a sample of 869 people ranging between the ages of 9 to 18 who used vending machines in the United States, 41.3% of them use vending machines which allowed round the clock access. Out of the same total, 38.8% used the vending machines between 1-2 days per week while 51.6% used the vending machines more than 3 days per week. It was found via surveying these people, that 51% used vending machines for chilled beverages (non-dairy) whereas 33% used them for snacks and other candy products. The remaining 16% was attributed to dairy and other items[17].

Over the last decade, lifestyle changes have resulted in an increasing shift in the usage of vending and snack machines by customers. Academic institutions and offices account for roughly 37% of vending and snack machines. However as mentioned before, there has been limited literature which concentrated fully on investigating consumer behaviour and their experiences and interactions with vending machines. One of the first studies, done by Manhattan College on consumers' experiences and opinions with vending machines, found that customers recognise that vending machines are useful and beneficial. Part of this study also found that consumers are not really satisfied with their vending machine experiences and that other types of vending machines such as music CDs and stationery are less frequently used[18].

6.3 Passive infra-Red (PIR) Sensor Systems

To facilitate its functions, vending misers have an accompanying device known as a passive infra-red (PIR) motion sensor. The PIR sensor is essentially an electronic device that is used to measure infra-red light (undetectable by humans) which radiates from a body with a temperature different to that of the environment when it passes within the sensor's field of view. These types of sensors do not have a built in infra-red source like other active sensors and the range of these sensors can usually extend to 30ft (9.1m).

The PIR sensor allows light to enter through the front of the sensor face which is made up of smaller pyro-electric materials that form thin films. The materials usually comprise of caesium nitrate or cobalt phthalocyanine and allow the conversion of light energy into tiny electrical signals. Silicon is used to cover and protect the light sensing elements and the sensor itself is encased to protect against outside noise, humidity and temperature[19].

The PIR sensors are used in conjunction with the vending misers for the following three main reasons[20]:

- PIR motion sensors detect objects without requiring any localisation based devices
- PIR motion sensors can function in areas of very low luminosity and can detect changes in temperature for easy human body detection
- PIR motion sensors are relatively inexpensive and easy to install and use, and processing data from the sensor is easier than that of ultrasound or a vision device

There are a number of websites which market vending/energy misers and claims of functionality and operational features will have to be referenced against patents or articles. However, as mentioned previously, within the scope of this project, only vending misers which fall into the category of BC Hydro's financial subsidy will be considered. Even though snack misers do not fall into this category, one will be selected based on cost and ease of installation. Information regarding these products will be obtained from product data sheets, installation guides and features.

The combination of previous research on how miser introduction has affected behavioural patterns of vending machine users will be able to assist in the efforts of this pilot project.

7.0 Data Sources & Methodology

7.1 Location Selection

The two sites chosen to conduct this vending and snack miser project were the basement of the Leonard S. Klinck Building and the second level of the Walter C. Koerner Library. The initial location that was intended with the support of the Administration Manager of Green College, Mr. Clark Lundeen, was the common area in Green College which housed both a vending and snack machine in the basement. However, through communications with Ms. Victoria Wakefield, the Purchasing Manager, Student Housing & Hospitality Services, it was realized that the Green College location was not conducive due to logistical reasons. The electrical outlets were situated at inaccessible locations (out of view and reach), behind the vending and snack machines and as a result would have had to be moved to access the outlets.

Another deterrent was the lack of overhead space above the machine where the PIR motion sensor was to be installed. The suggested minimum overhead requirements were twelve inches of space but the basement of Green College only had six inches available. This would mean either having to refurbish the sensor mounted bracket for use or affix the sensor to the ceiling.

The vending machines are not the property of UBC and thus moving the machines would have required approval and coordination with the respective vendors. This proved to be a tedious process as the availability and reliability of the vending company staff was uncertain since the machines would have had to be moved a number of times throughout the project lifetime. Ms. Wakefield obtained permission from the respective machine vendors regarding the investigation and installation of the load managing devices.

Given that the project had to be completed within a specific timeframe, other viable vending/snack machine locations were sought. The machines and their location on the lower level of the common area at Place Vanier Residence were considered, however the same problem was encountered as the Green College environment. The chilled beverage vending machine located in the basement floor of the Leonard S. Klinck Building was selected due to the following reasons:

- The vending machine selected at this location was not an Energy Star rated machine and would account for a sample of the 80% of non-Energy Star rated machines on campus.

- The environment in which the vending machine was situated was low traffic compared to Koerner Library. Occupancy time was estimated at 65 hours per week.

- Like the location in Koerner Library, the environment in Klinck was ideal in terms of ease of accessibility to the electrical outlets and the fact that there was overhead space available for sensor and bracket installation.

The Walter C. Koerner Library was selected due to the following reasons:

- The vending machine selected at this location was an Energy Star rated machine and would account for a sample of the 20% of the Energy Star rated machines on campus.

- The environment was more ideal in terms of easier accessibility to the electrical outlets, in addition to which both machines were located within 2 metres of each other.

- There was more overhead space available for sensor and bracket installation.

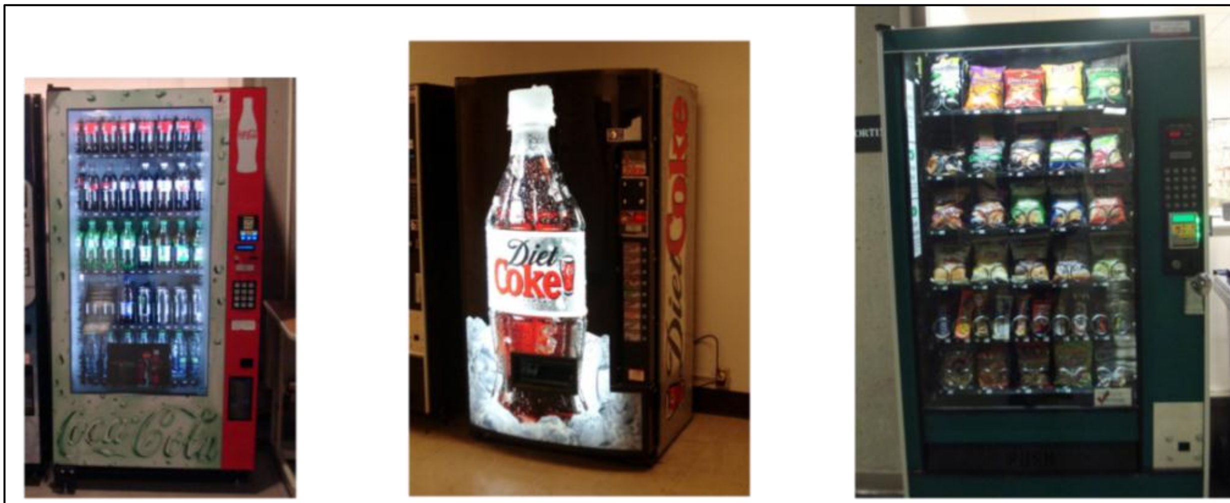
- This location can be considered a high traffic area and allows for the capture of a larger percentage of the student population since it is not restricted to graduate residents. Occupancy time was estimated at 86 hours per week.

- The vending machine and snack machine that were the subject of the investigation, both accepted coins, bills and cards as payment options and thus ensured that a large customer audience could be captured.

The chilled beverage vending machine in Koerner Library is classified as a ‘Class A’ beverage machine because it utilises a transparent glass front and a shelf mechanism where customers could see the next product that is to be vended by the machine[21]. On the other hand the chilled beverage vending machine in Klinck Building is classified as a ’Class B’ beverage machine because it has an opaque front and utilises a stacking style mechanism, and customers cannot usually see what product is vended (See Figure 2).

The following are pictures of the vending and snack machines from which data was obtained during this pilot project.

Figure 2: Vending & Snack Machines Evaluated



Energy Star Vending Machine (Refrigerated Beverages) Koerner Library

Conventional Vending Machine (Refrigerated Beverages) Klinck Building

Snack Machine (Unrefrigerated Snacks) Koerner Library

7.2 Watt Meter & Data Logging Selection

Initially, the borrowing the Kill-A-Watt meter from UBC Library was considered; however these meters did not have storage capability and the range of electrical attributes that were desired to be measured. After comparison of different watt meter types, the one that was selected to measure power and other attributes of the vending machines, was the *Watts Up? Pro Extra Storage Meter*. This was best suited for recording and storing data internally over long periods (a number of days) and comes with USB interface and manufacturer software which allows easy transfer to a computer for data analysis. See Appendix A for watt-meter specifications.

The two (2) Watts Up? Pro ES meters were calibrated by use of the accompanying software: Watts Up USB Data Logger, which was downloaded from the manufacturer's website. The first meter was plugged into the electrical outlet and the USB cable was then used to connect the meter to a laptop with the installed software. The following parameters and settings were selected for the watt-meter, and also done for the second watt-meter:

Logged Items

o Volts	o Maximum Watts	o Amperes	o Watt-Hours
o Watts	o Minimum Watts	o Cost	o Monthly Cost

Logging Interval: 2 minutes (every 2 minutes the meter would collect the above data)

Duty Cycle Threshold: 250W

Cost per kWh: $0.052 (UBC blended cost of electricity)

7.3 Baseline Data Collection

On October 19th, the vending and snack machines were unplugged from the electrical outlets in Koerner Library and powered down. The beverage machine was plugged into the first *Watts Up? Pro ES Meter*, which was in turn plugged into the electrical outlet. This step was repeated for the snack machine and the time of installation of the watt-meters was noted. The watt-meters were positioned in such a manner that they did not affect building occupant traffic flow and were also not prominently visible.

The baseline measurement period lasted for 10 days (until October 19th), after which the vending and snack machines were moved, and the watt-meters recovered. The meters were then connected via USB cable to a laptop and the data recorded in the meters was transferred and saved for analysis.

Baseline data was collected from the vending machine in Klink Building from November 13th and lasted 7 days (until November 20th).

7.4 Miser Selection & Installation

The vending and snack misers that were selected for use in this pilot project were:

- The USAT VM-170 (Easy-Install Vending Miser with PIR Sensor) and
- The USAT SM-170 (Easy-Install Snack Miser with PIR Sensor)

These misers were chosen based on the ease of installation which did not require any additional tools compared to other available models. (See Appendix B for vending miser and snack miser specifications)

The installation steps for the VM-170 are as follows:

1. The watt-meter was unplugged from the electrical outlet, thereafter which the vending machine was unplugged from the watt-meter.
2. A cloth was used to carefully wipe and dry the area where the vending miser was to be attached.
3. The Velcro adhesive adheres best to surfaces above temperatures of 18°C so the exterior panel temperatures of the vending machine were obtained and it was decided that the vending miser would be installed to the back of the machine.
4. The white plastic adhesive protecting the Velcro at the back of the vending miser was removed and the miser was then secured firmly by pressing it to the top of the back of the vending machine. This location was used as:
    a. The sensor bracket was not adjustable and thus the sensor was not able to swivel to the best possible position. This mechanical design could be improved if the sensor was rotatable.
    b. The lower portion of the vending machine is subject to the hot exhaust from the compressor which may cause the miser to malfunction.
    c. The side of the machine was not suitable as the sensor would not have been at the best angle.
5. The vending machine was then plugged into the outlet in the vending miser.
6. The bracket housing the sensor and connecting cable was placed and secured on top of the vending machine. Given that the ceiling where the vending machines were located on the second floor of the Walter C. Koerner Library had enough overhead space, the sensor was placed on top.

7. During installation, the sensor head was made to point in the direction of the vending machine to ensure proper occupancy detection. There were no air ducts nearby so this reduced the risk of false triggering of the sensor system via the warm air flow.
8. The cable coming out of the PIR sensor unit was then plugged into the socket on the vending miser by means of the Ethernet connector at the end of the cable.
9. Finally, the vending miser was plugged into the Watts Up? Meter, which was in turn plugged into the electrical outlet.
10. The PIR sensor was allowed to 'warm-up' and stabilise for a few minutes, during which the green LED light on the sensor blinked on and off. After this process, the green sensor light came on when there was movement within the field of view of the sensor. This validated that the sensor was operational and can detect motion. Communication between the sensor and the vending miser was verified by observing the red LED light on the miser which mirrored the blinking state of the green light on the sensor. The Orange LED light on the miser only came on while the compressor was on.

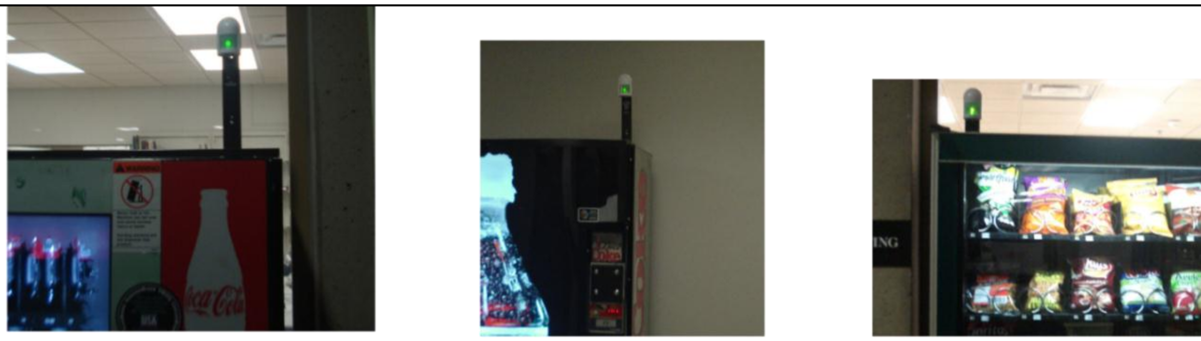
The initial placement of the misers was thought to be at the side of the machines, as the machines could not be moved due to their large mass and vending policy of only being moved when fully emptied. However upon receiving the snack and vending misers, it was found that the bracket for placement of the sensor and securing the miser was non-adjustable. This meant that the sensor could not swivel about its axis and such limited the placement options (See Figure 4).

It was also noted that based on sensor testing and validation, the PIR sensor did not detect motion through glass. This was advantageous in the case of the second level of Koerner Library which contained glass panels and doors near the stairwells and entrances. It was thought that the sensor would have detected unnecessary 'background' motion through these glass panes and thus affected the operation of the misers, but fortunately this was not the case. The range of the PIR sensors extended to approximately 15 metres.

Installation of both the vending and snack misers on the two machines took around 1 hour, with most of the time being allocated to sensor positioning and testing, to ensure that they were in the best possible location on top of the machines to detect optimum occupancy. The actual installation of the misers, mounted brackets and plug connections took approximately 10 minutes for each machine.

The following are pictures of the vending and snack machines from which data was obtained during this pilot project after the respective vending and snack misers were installed. The only visible part of the load managing system was the PIR sensor located on top of the machines.

Figure 3: Vending & Snack Machines with VM-170 & SM-170 Installed – PIR Sensor View



Energy Star Vending Machine With VM-170 Vending Miser

Conventional Vending Machine With VM-170 Vending Miser

Snack Machine With SM-170 Snack Miser

Figure 4: Vending Miser & Snack Miser Installed in Koerner Library (back view)

Figure 5: Schematic Layout of Vending & Snack Machines

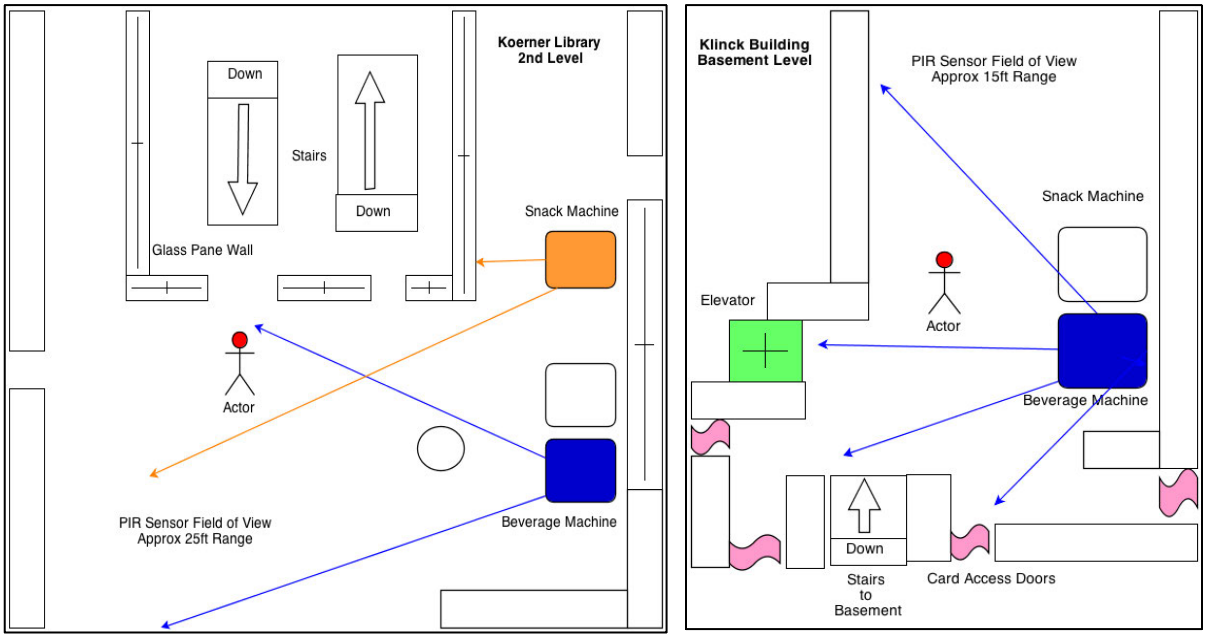


Figure 5 shows the schematic diagrams (not to scale) of Koerner Library and Klinck Building along with access routes and the approximate field of view of the sensor system installed in conjunction with the misers. As mentioned before, the infra-red sensor cannot penetrate glass as shown above in Koerner Library. The card entry doors are only accessible to staff with key cards on the basement level in Klinck Building and the area for possible traffic flow is smaller than that compared to Koerner Library; this despite a greater number of entry points to access the vending machine.

7.5 Vending/Snack Miser Data Collection

The vending/snack miser savings measurement period also lasted 10 days for the machines in Koerner and 7 days for the vending machine in Klinck, after which the vending and snack machines were moved and the watt-meters recovered. However, the vending and snack misers were re-plugged into the electrical outlets for standard and continuous operation. The meters were then connected via USB cable to a laptop and the data recorded in the meters was transferred and saved for analysis.

The vending machines and watt-meters were personally inspected daily to ensure that they were operational and there were no signs of tampering or interference. The following sign labelled number 2, courtesy of Ms. Lillian Zaremba, were made as an attempt to deter tampering and placed on the vending machines as well as the watt-meter equipment and sensor brackets. Also in the picture labelled 1 and 3 are the watt-meter power connections and the snack machine power connections respectively.

Figure 6: Power Connection with Watts Up? Meter Setup & Anti-Tampering Signs

7.6 Vending Product Temperature Data

During the baseline measurement period, temperatures of the chilled beverage products in the vending machine were obtained on a daily basis.

- Temperatures were taken at the mid-section of the first bottle in the front row of all five trays housed in the glass-front panel vending machine.
- The timing of the temperature recordings was such that they were taken at approximately the same hour each time of recording, and was done so after the compressor had shut off and had completed one of its cycles.
- The same procedure was repeated and temperatures recorded during the vending miser savings measurement period.

The temperatures of the beverages were obtained by use of a *ST-8835 Non-Contact Infrared Thermometer* and the readings were obtained from either self-purchasing of beverages or with the approval of customers purchasing beverages from the vending machine. The operation of the thermometer is highlighted below:

i. The instrument was held by its handle grip and was then pointed towards the surface of the chilled beverage can/bottle.

ii. The trigger was then pressed and held in place which powered on the IR thermometer and activated a laser pointer. The built in screen on the thermometer displayed the temperature reading of the object that was focused on by the laser beam.

Table 1: Summary of Machines, Locations and Miser Types

Manufacturer	Model	Refrigerant	Vending Type	Location	Miser Type
Vendo	V-540	R134a	Chilled Beverages	Leonard S. Klinck Building	VM-170
Royal Vendors	RVRVV 500-64	R134a	Chilled Beverages	Walter C. Koerner Library	VM-170
Automatic Products	SNACKSHOP LCM3B	-	Snacks	Walter C. Koerner Library	SM-170

Table 1 above provides a summary of the machines, locations and miser types installed with all the machines having different manufacturers. Both chilled beverage vending machines used the refrigerant R124a, and makes use of a reciprocating compressor which compresses the refrigerant inside of a cylinder via the up-down action of a piston[22]. In Koerner, the chilled beverage vending machine housed both bottles and canned beverages on 5 tray levels, with 8oz. sizes. The snack vending machine housed edible items on 6 tray levels, in the form of chips and candy bars. The chilled beverage machine in Klinck housed 9oz. size beverages but was not a glass front door so the number of tray levels could not be determined.

7.7 Behavioural Survey Assessment

Prior to the installation of the misers, the behaviour of customers who used the vending and snack machines was noted. After the installation of the vending and snack misers, the behaviour of customers was observed unobtrusively at a distance. This involved:

- The manner in which the vending and snack machines were approached
- The customers' reaction to the vending and snack machine's new mode of operation (if any at all)

Surveys in the form of one page questionnaires were issued to customers willing to participate after the use of either beverage or snack machines (See Appendix C for sample of issued survey). This type of face to face survey was chosen as it allowed information to be gathered in a timely manner and on-site, as compared to an online survey. This took place over a period of 9 days.

8.0 Results

8.1 Conventional Vending Machine

Figure 7: Logged Baseline Power Readings of Conventional Vending Machine

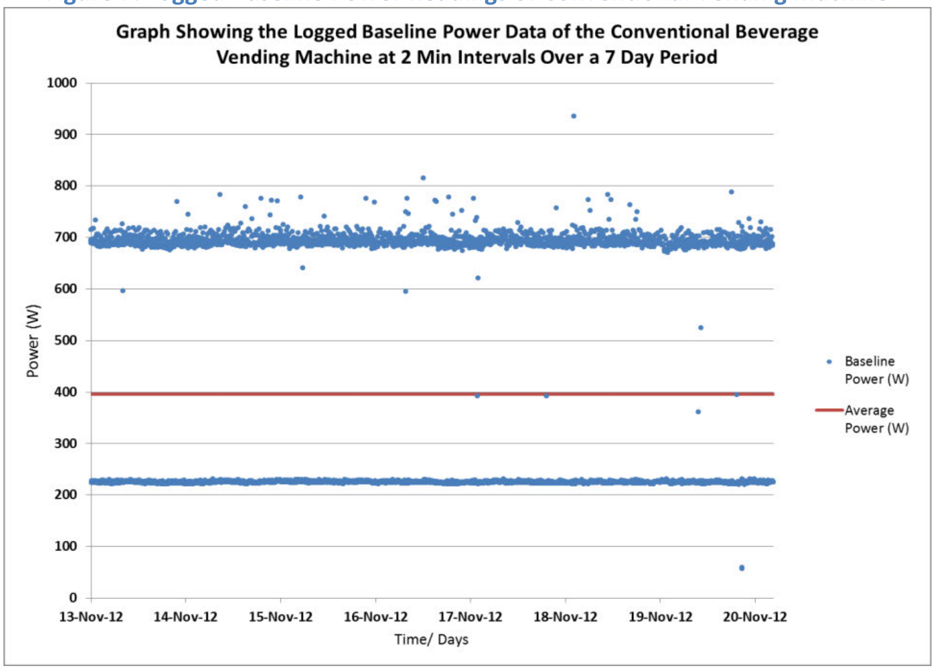
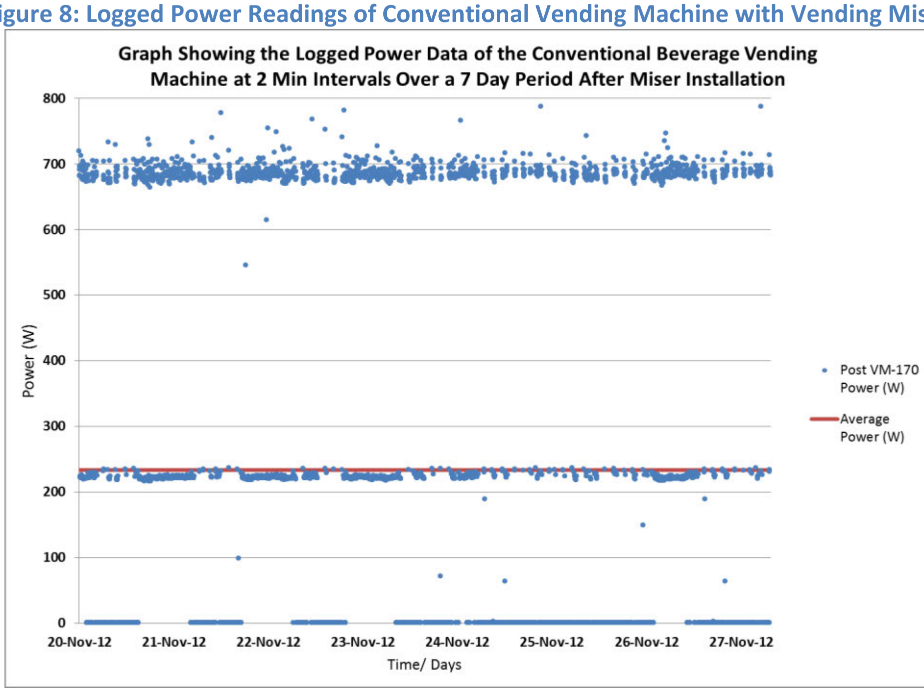


Figure 8: Logged Power Readings of Conventional Vending Machine with Vending Miser



8.2 Energy Star Vending Machine

Figure 9: Logged Baseline Power Readings of Energy Star Vending Machine

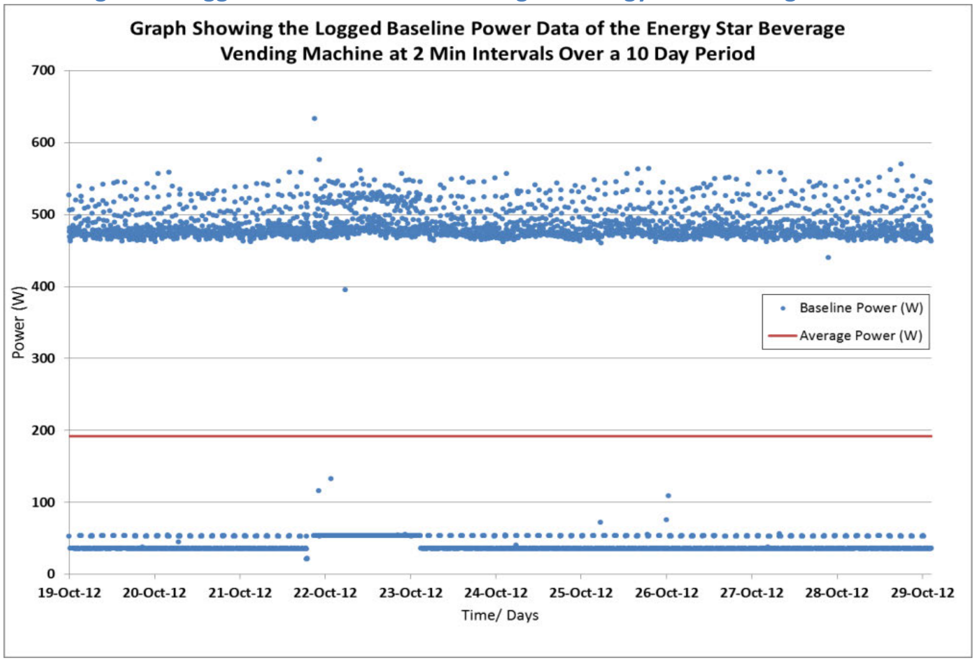
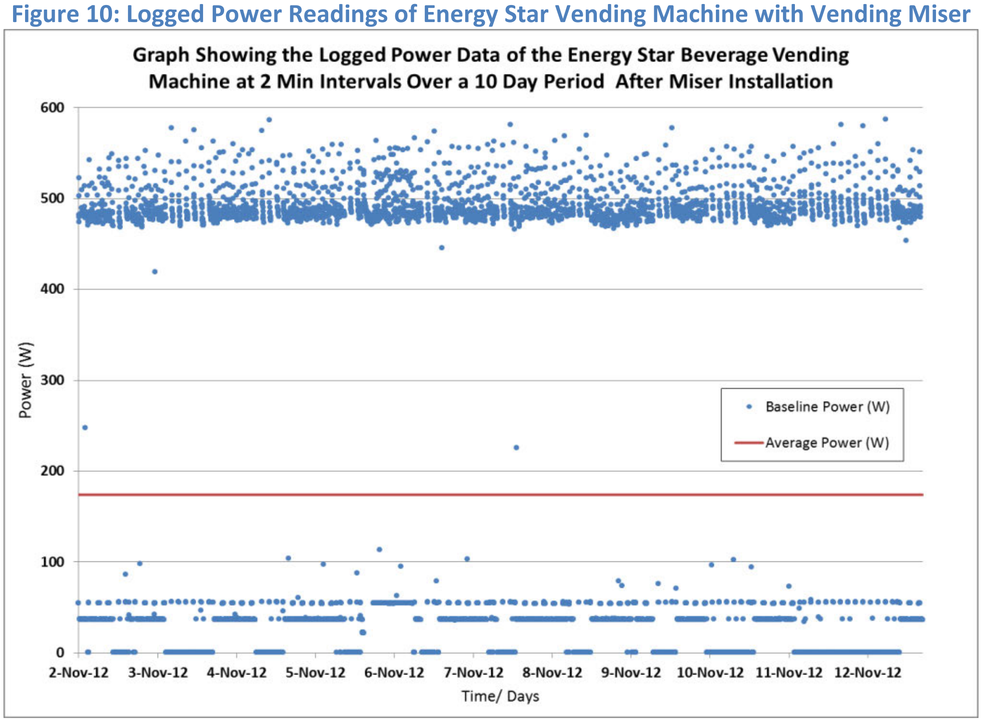


Figure 10: Logged Power Readings of Energy Star Vending Machine with Vending Miser



8.3 Snack Machine

Figure 11: Logged Baseline Power Readings of Snack Machine

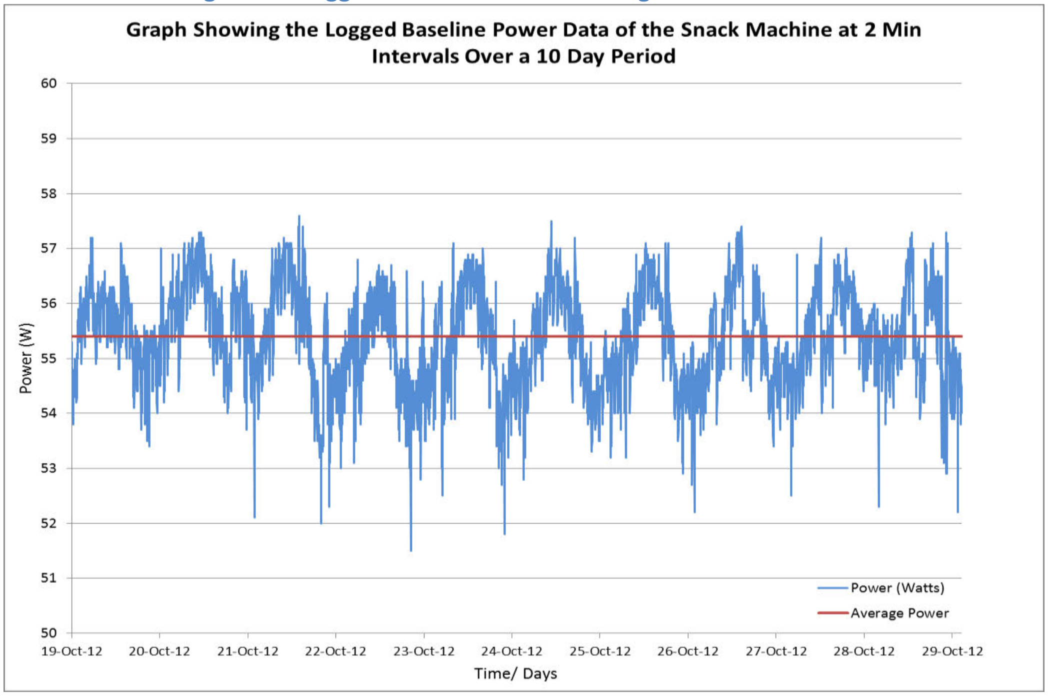


Figure 12: Logged Power Readings of Snack Machine with Snack Miser

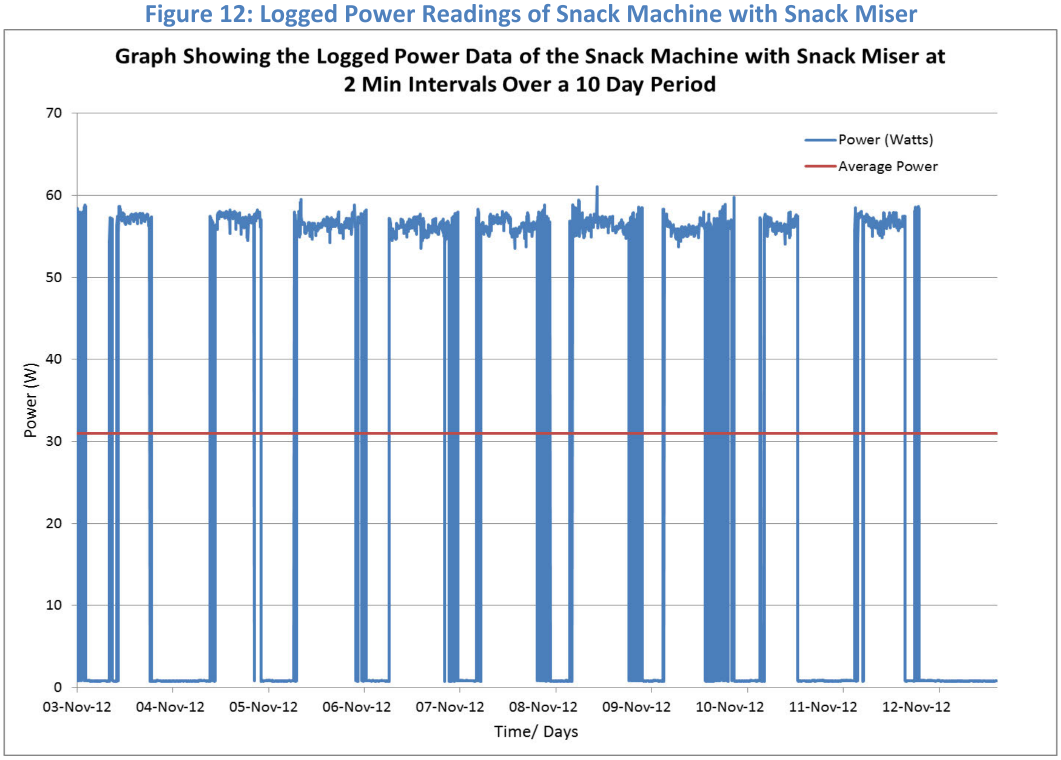


Figure 7 illustrates the power data points over the 7 day baseline period for the conventional vending machine in Klinck Building. More than four thousand data points were logged every 2 minutes by the watt-meter and as such this was the best graphical representation of these points, which if connected will display a series of continuous cycles (discussed in *Analysis of Results*). During these cycles the power varies between 690W and 223W per average cycle and was consistent throughout the 7 day period. The average power was calculated to be 395W and was characteristic of conventional vending machines as it fell within the 300W to 500W range.

Figure 8 illustrates the data points over the same logging interval and time period for the week following the VM-170 installation on the machine. The pattern is similar to the baseline chart with the exception of new data points near the bottom of the power axis which indicated almost zero power demand during those periods. The density of the points along the 690W and 223W mark showed a decline and the average power demand of the vending machine was now found to be 233W, indicative of a 41% drop.

Figure 9 illustrates the power data points over the 10 day baseline period for the Energy Star vending machine In Koerner Library. These data points totaled to more than seven thousand at 2 minute intervals and follow a similar pattern to the conventional machine. Nevertheless, they cover a smaller power range between 475W and 36W average. Between two particular days, October 22nd and 23rd (Monday and Tuesday), there was an anomaly in the power cycle which could have been due to the re-stocking of the beverages in the machine by the vendor or an increase in demand for power by the vending machine during that time period. The average power demand over the 10 day period was found to be 192W.

Figure 10 illustrates the power data points after the VM-170 was installed on the Energy Star machine. The data points plotted are now distributed more unevenly below 100W and shows the areas where the power demand is near zero, indicating the times the machine entered energy save mode. Compared to Figure 8, the frequency of these points is less which indicated that the Energy Star machine did not saved as much power compared to its baseline readings. The average power demand over the 10 day savings period was found to be 174W which represents a 9.7% decrease. It can be noted that on November 6th (Tuesday) there was also an increase in power demand shown in Figure 10 above.

As can be seen in Figure 11, the power profile of the snack machine in Koerner Library resembles that of a sinusoidal curve between the limits of 51W and 58W throughout the data collection period. The average power usage of the snack machine during this baseline period was calculated to be 55.4W. After the SM-170 was installed, the power profile of the snack machine completely changed and took a stepped shape, as shown in Figure 12. This power pattern conforms to the literature and previous studies, as the snack miser altered the operation of the snack machine by controlling the fan cycle based on occupancy detection. The average power usage of the snack machine after miser installation was 31.0W, a reduction of 22.4W for the same 10 day period. The magnitude of power reduction with the use of the SM-170 is therefore equivalent to 44%.

Figure 13: Comparative Vending & Snack Machine Power Demand With & Without Misers

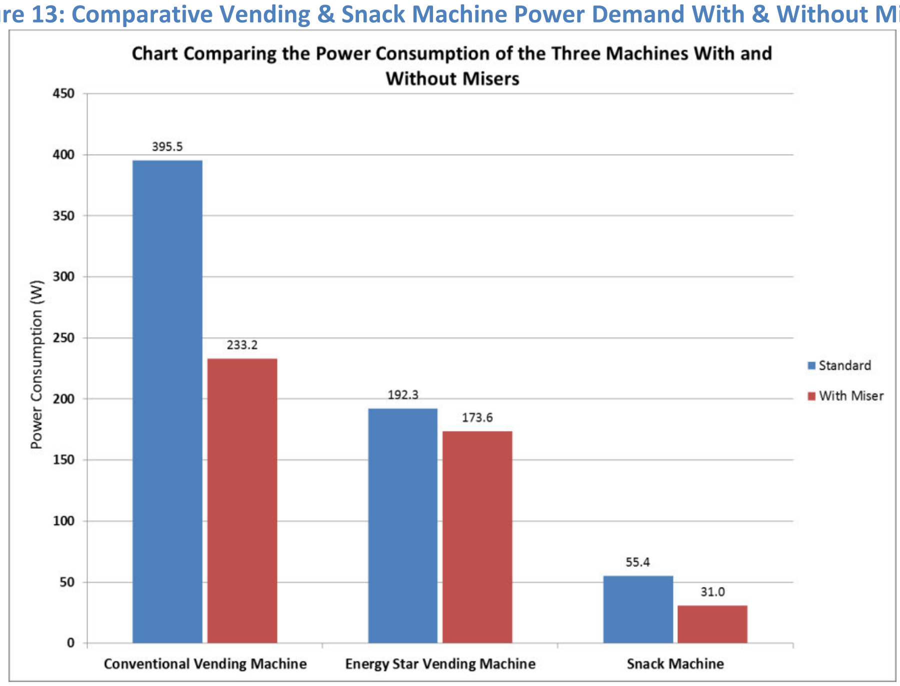


Figure 13 summarizes the comparative power demand of the machines before and after the miser units were installed, thus proving vending and snack misers are indeed capable of reducing power demand, but to varying degrees. It can be seen that the misers were most effective on conventional vending machine, followed by the snack machine and energy star vending machine in that order. The effectiveness of the misers with respect to power reduction for the conventional, Energy Star and snack machine is 41%, 9.7% and 44% respectively.

8.4 Vending & Snack Machine Power Breakdown

Figure 14: Vending Machine Component Power (Compressor On)

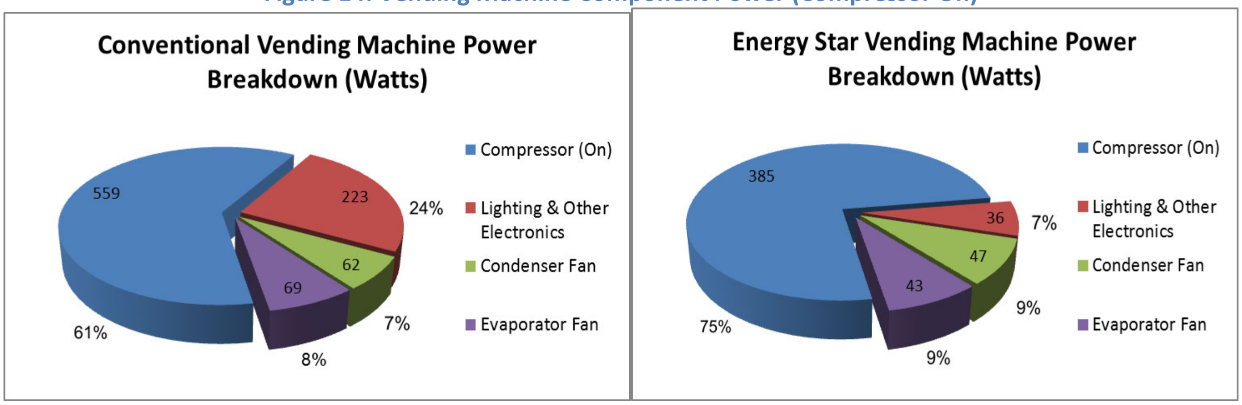


Figure 15: Snack Machine Component Power (Fan On)

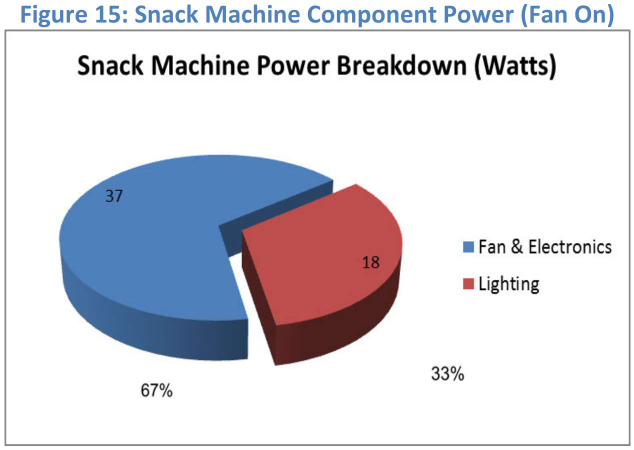


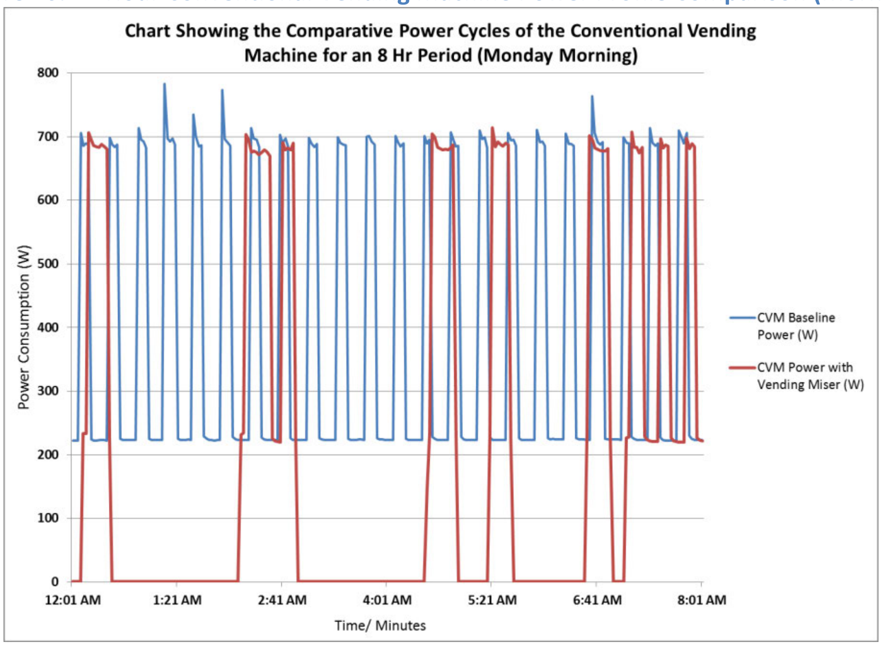
Figure 14 shows the power breakdown of both the conventional and Energy Star vending machine. These values are averages obtained from the data recorded by the watt-meter by evaluating the power profiles in detail. However, the power ratings of the condenser and evaporator fan were obtained from literature on a previous study[21]. The conventional vending machine displays the typical component power demand, as the compressor system accounts for 61% of the power demand when it is on. The lighting system uses a significant amount of power due to the design of the machine which requires heavy backlighting to keep the it well lit (See Figure 2). The power requirements of the compressor system in the Energy Star machine are less than that of the conventional machine even though it accounts for about 75% of the total power. The lighting and other electronics are also significantly less due to the LED lights in the Energy Star machine.

Figure 15 shows the breakdown of component power in the snack machine. It comprises a fan to dehumidify the air, the lighting in the form of an 18W lamp at the top inside of the machine and the electronic and dispensing system which are active during purchases. The components are simple as this is an unrefrigerated snack machine.

9.0 Analysis of Results

9.1 Extensive Power Analysis

Figure 16: 12 Hour Conventional Vending Machine Power Profile Comparison (Morning)

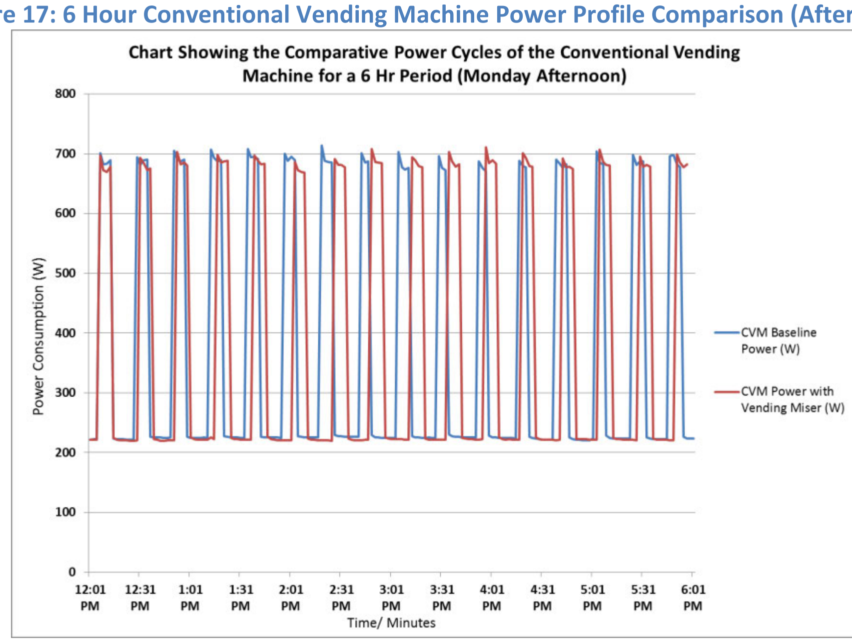


Looking at the 8hour power profile for a Monday morning in Figure 16, it can be seen that during the baseline power demand there were approximately 22 compressor cycles from midnight to 8am. Post vending miser installation, there were approximately 9 compressor cycles for the same time frame. From midnight to 7am (the opening time of the Klinck Building on Mondays), there were 20 baseline compressor cycles which lasted on average 8minutes with delay periods of approximately 10minutes in between cycles. The corresponding 6 post miser installation cycles lasted on average 23minutes with 55minute average delay periods between cycles.

These comparisons were made during closing hours and when there was supposed to be zero occupancy. It can be observed that the vending miser cycles last almost thrice as long as the baseline cycles but the delay periods are almost five times as long. It is at these times that the conventional vending machine with the VM-170 installed saves power in its energy saving mode where it only consumes about 0.8W on average (watts used to power the vending miser alone as the lights and compressor are off during these times). As can be seen with the VM-170 installed, there were extended 90minute delay times as seen between 2:45am and 4:30am.

Consequently, it can be deduced that the 220W average is used to power the lighting and electronic system as well as the vending miser. It can also be noted that the peak power demand of the machine after miser installation was roughly the same hovering at around 700W.

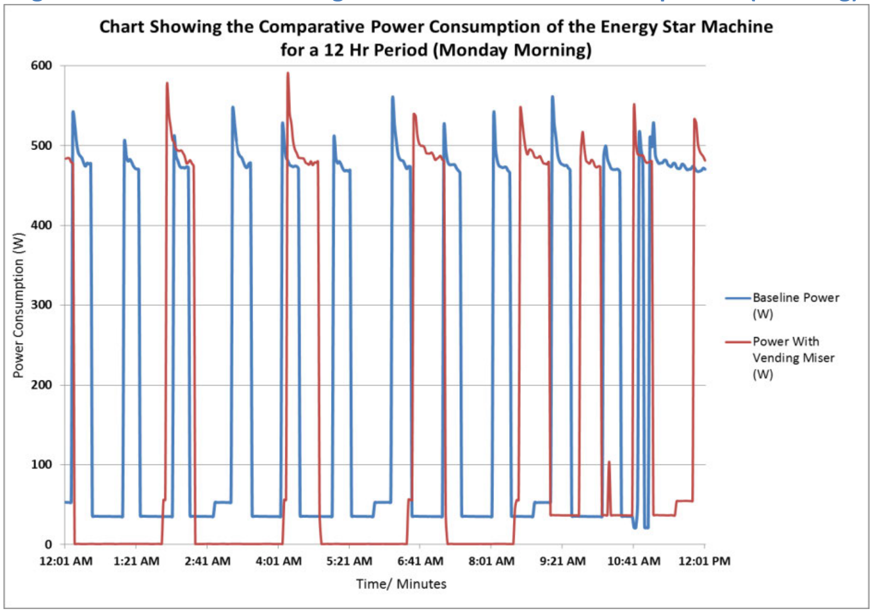
Figure 17: 6 Hour Conventional Vending Machine Power Profile Comparison (Afternoon)



Continuing with the 6hour power profile for Monday afternoon, Figure 17 shows that during the baseline power demand there were approximately 16 compressor cycles from noon to 6pm. Post vending miser installation, there were approximately the same number of compressor cycles for the same time period. The average baseline compressor cycle lasted 6minutes with delays of approximately 12minutes between each cycle, which is almost the same as those between post-miser installation cycles. It was also observed that during opening hours when there is occupancy, there are almost no savings due to the similarity in cycle and delay times.

When comparing both graphs and data after vending miser installation, it can be deduced that delay periods between cycles are almost increased by a factor of 4.5 during non-occupancy hours as compared to occupancy hours. This indicates that in order to achieve maximum energy savings, minimal occupancy or extended periods of zero occupancy are required. The Klinck building location is ideal for such savings as it is opened from 7am to 8pm on weekdays (65 hours) and closed on weekends and public holidays. However some staff has access after-hours via key-cards and this may have resulted in extended occupancy hours.

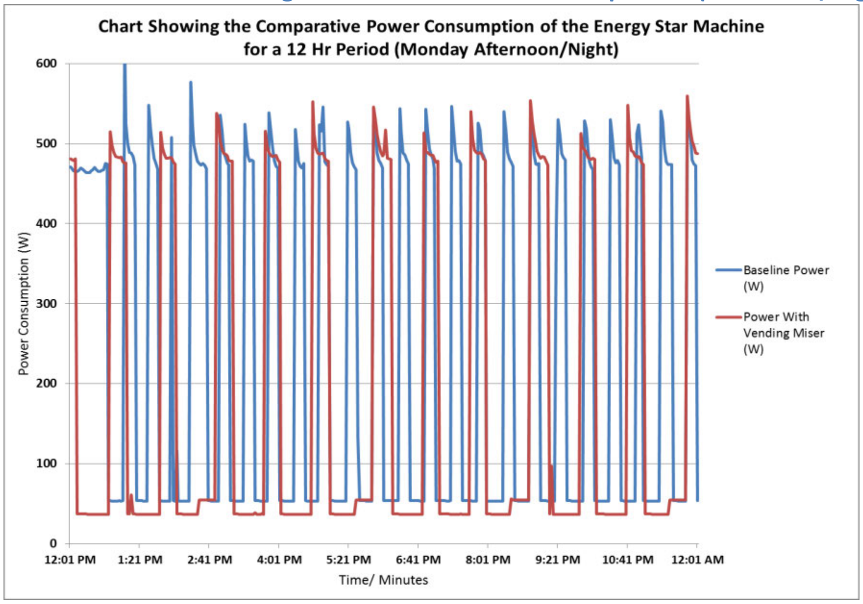
Figure 18: 12 Hour ES Vending Machine Power Profile Comparison (Morning)



Looking at the 12hour power profile for a Monday morning in Figure 18, it can be seen that during the baseline power demand, there were approximately 13 compressor cycles from midnight to noon. Post vending miser installation, there were approximately 7 compressor cycles for the same period. From midnight to 8am (the opening time of the library on Mondays), there were 3 compressor cycles post miser installation which lasted 34minutes, 30minutes and 40minutes respectively with delay periods of 98minutes and 95minutes between the cycles. The corresponding baseline cycles lasted 16minutes, 20minutes and 20mintues respectively with 35minute average delay periods between cycles.

These comparisons were made during closing hours, when there was supposed to be zero occupancy. It can be observed that the vending miser cycles last almost as twice as long as the baseline cycles but the delay periods are almost thrice as long. It is at these times that the vending machine with the VM-170 installed saves power in its energy saving mode since it only consumes about 0.8W on average. This was always less than 1W, the amount which was required to power the vending miser.

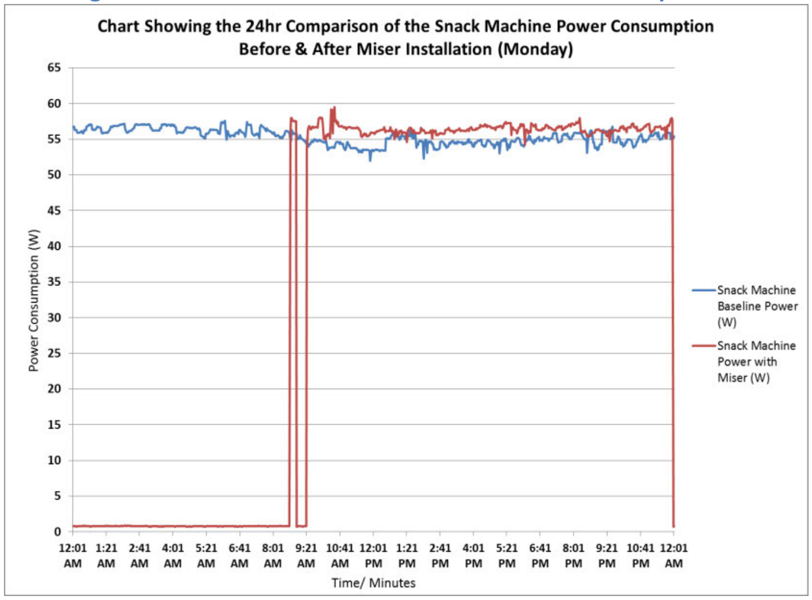
Figure 19: 12 Hour ES Vending Machine Power Profile Comparison (Afternoon/Night)



Continuing with the 12hour power profile for Monday afternoon/night in Figure 19, it can be seen that during the baseline power demand there were approximately 22 compressor cycles from noon to midnight. Post vending miser installation, there were approximately 12 compressor cycles for the same duration. The average baseline compressor cycle lasted 12minutes with delays of approximately 14minutes between each cycle. This is shorter on both counts compared to post-miser installation cycles which lasted on average 18minutes per cycle with delays of about 40minutes.

It was observed that the vending miser cycles last almost 1.5 times as long as the baseline cycles but the delay periods are almost thrice as long. It is at these times that the vending machine with the installed VM-170 saves power in its energy saving mode where it only consumes about 36.7W on average (used to power the lighting and electronic system and the vending miser). When comparing both graphs and data after vending miser installation, it can be deduced that the compressor cycle times and delay periods between cycles are both almost reduced by 50% during occupancy hours as compared to non-occupancy hours. This indicates that in order to achieve maximum energy savings, minimal occupancy or extended periods of zero occupancy are required.

Figure 20: 24 Hour Snack Machine Power Profile Comparison



With respect to Figure 20, it shows that there is no cycle system for the snack machine but instead fluctuations of power around a mean point with minimum power being 51.1W. When the snack miser was introduced and worked in conjunction with the occupancy sensor system, the average number of cycles per day was related to the occupancy of the environment around the machine. From midnight on Monday, the machine was in energy save mode, with the only power being consumed by the SM-170 snack miser in standby operation of about 0.8W. During this time the lights and fan did not come on as the PIR sensor detected no occupancy. This continued until opening hours of Koerner Library at 8am, after which the sensor detected motion, and activated the lighting system and fan within the machine for approximately 15minutes.

When no motion was detected during the 15minute period, the machine was powered down into energy save mode again until about 9:21am when activity on the second level of the library increased and was maintained. Thus, there was no 15minute delay period for the machine to enter its energy save mode again until midnight. It was also observed that during this time, the snack machine's power demand was strangely higher than the baseline demand by about 2.5W. This may be accounted for by the usual variations in power demand for that time as post-baseline readings took place the following week.

9.2 Temperature Data Analysis

This section deals with the temperatures of beverages taken from the Energy Star vending machine to determine if there would be differences in beverage temperature after the installation of the VM-170.

9.2.1 Energy Star Vending Machine

Figure 21: Baseline Temperature Profiles of Energy Star Vending Machine Products

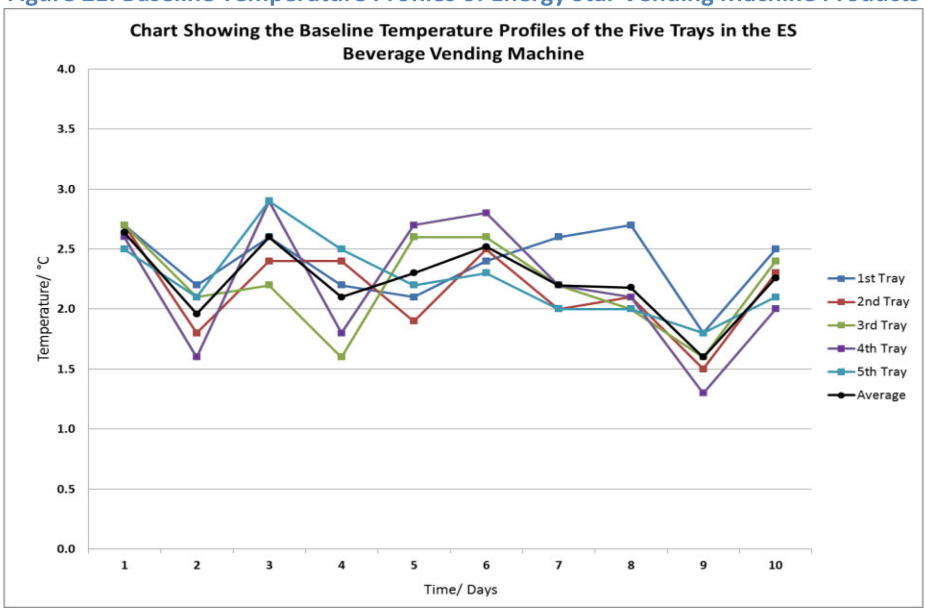
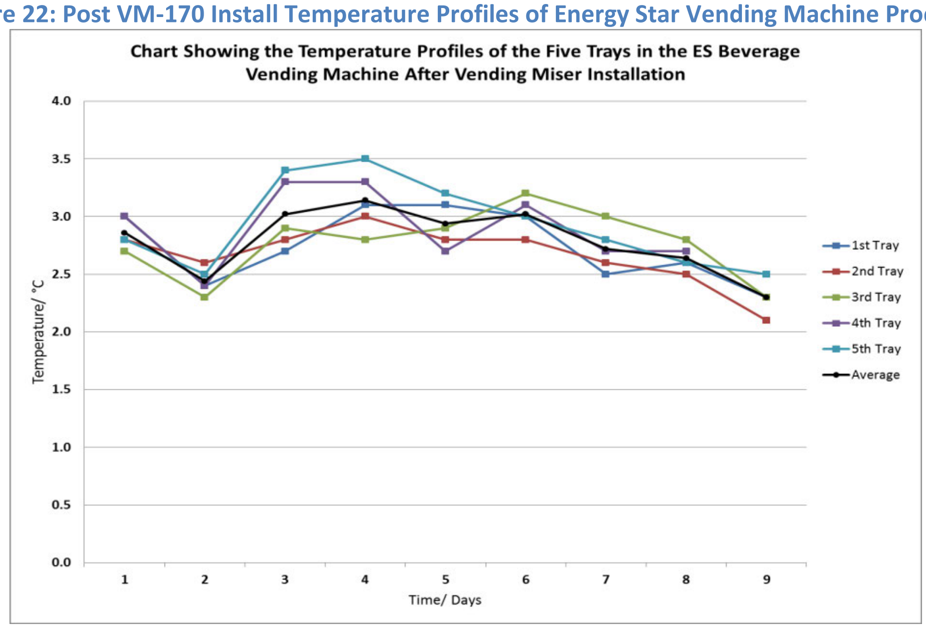


Figure 22: Post VM-170 Install Temperature Profiles of Energy Star Vending Machine Products



The temperature profile in Figure 21 of the beverages in the Energy Star rated machine show that they are consistent with the pre-programmed temperature of 35.5F (1.9°C). The temperatures of the beverages spanned from 1.3°C to 2.9°C and this could be due to the systematic way in which the vending machine cools its beverages, or the amount of usage by customers. The first and last drop in temperature readings both took place on a Sunday (days 2 and 9) and seem to indicate that the beverages are colder on the weekends which may be attributed to less frequent usage. Days 5 to 8 recorded higher average temperatures and this may be linked to more frequent usage during the week.

After the installation of the VM-170 miser on the beverage machine, the temperatures of the beverages taken were plotted as seen in Figure 22. The temperature profiles follow an almost similar pattern to that of the baseline profile, except that the temperatures now range from 2.1°C to 3.5°C which shows that the average temperatures of the beverages have increased after the installation of the vending miser. The same trend on days 2 and 9 can be seen with both having low beverage temperature readings and day 3 having high temperature readings relative to the other days. Data for the 10th day could not be obtained as that day was a public holiday and as such Koerner Library was closed.

Figure 23: Product Temperature Comparison Before & After VM-170 Installation

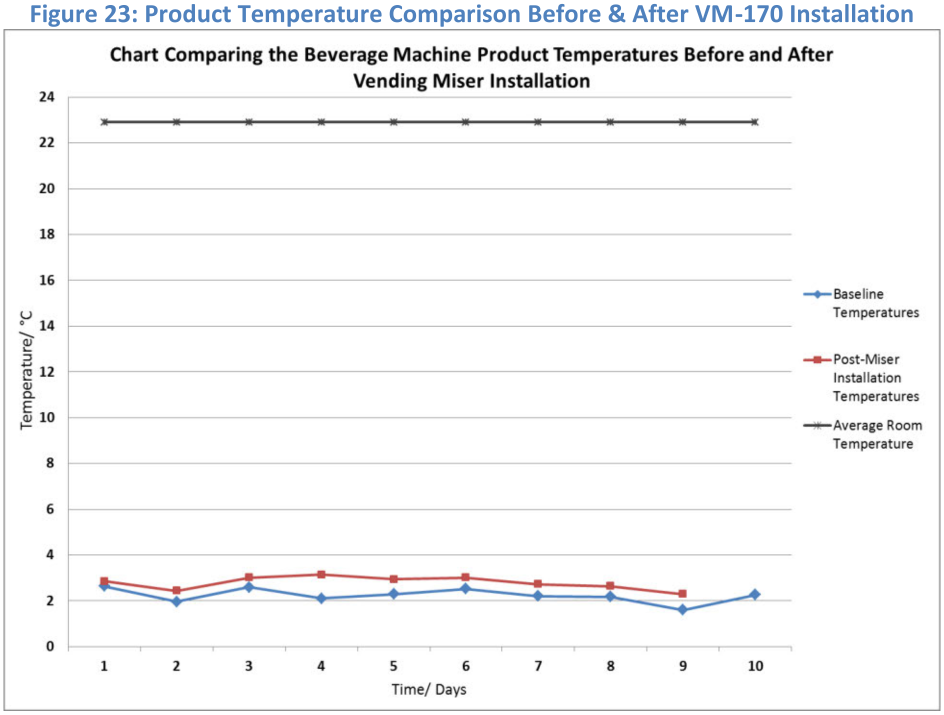


Figure 23 best illustrates the temperature profiles of the beverages before and after the installation of the vending miser, relative to the average room temperature of 22.9°C. This puts into perspective how small the differences in temperatures actually are, with the average temperature difference being 0.6°C between pre and post miser profiles. Even though there is an average increase of 0.6°C, the vending machine temperatures are still lower than the 4.4°C threshold stated by National Resources Canada. It can therefore be stated that the installation of vending misers does, in fact, increase the temperature of the vending products but not to a significant degree. (See Appendix E for tabulated temperature data)

9.2.2 Snack Machine

Figure 24: Baseline Temperature Profiles of Snack Machine Products

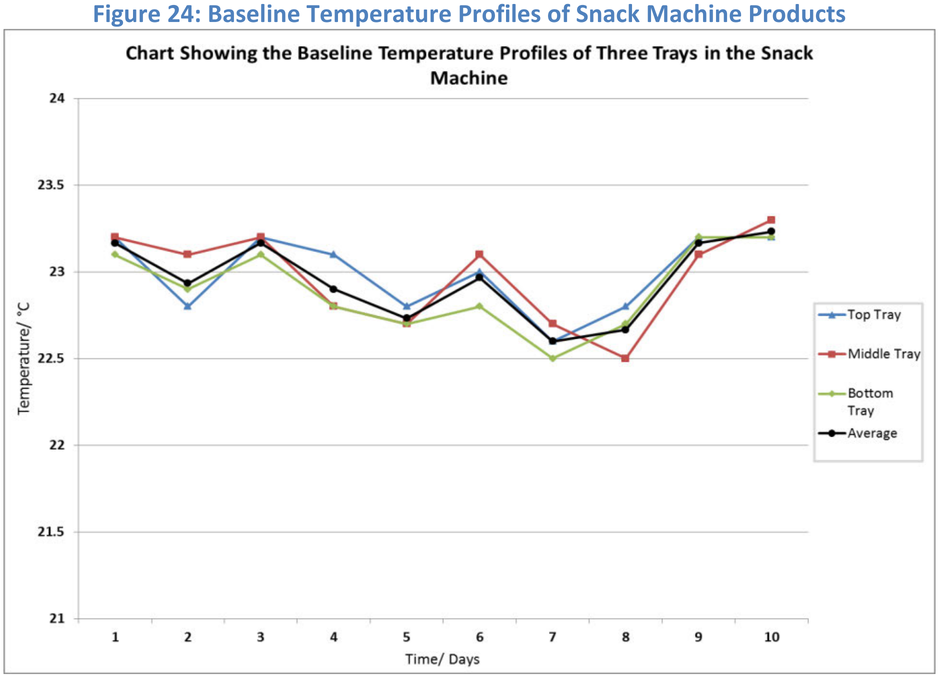
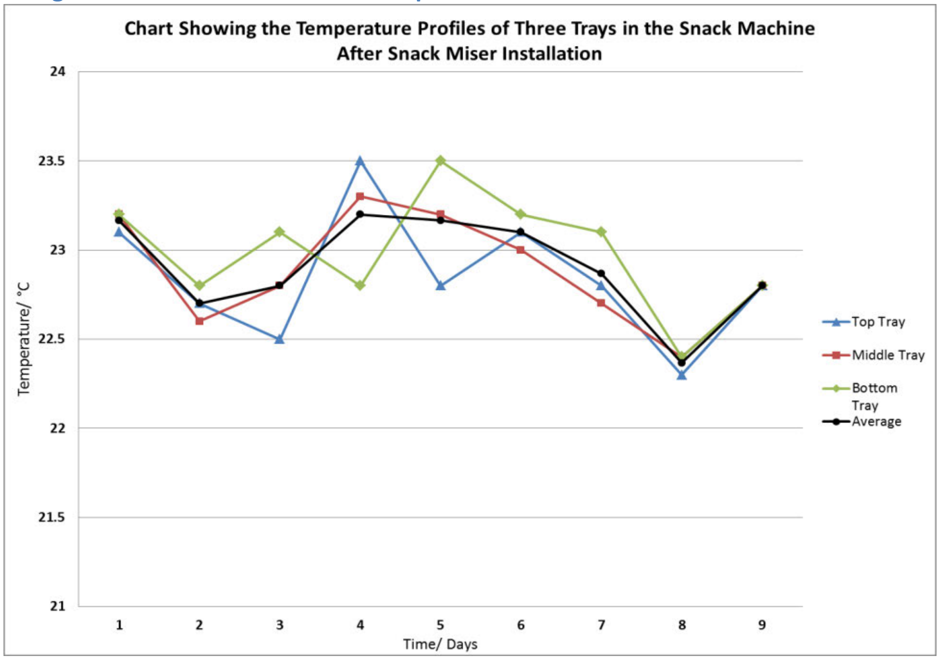


Figure 25: Post SM-170 Install Temperature Profiles of Snack Machine Products



The temperature profile in Figure 24 relates to snacks in the snack machine and show that the temperatures of the snacks spanned from 22.5°C to 23.3°C, which is a mere 0.8°C difference which could be due to the accuracy range (±1.5% of reading +2°C) of the IR thermometer or the minor fluctuations in room temperature. The temperatures follow a generally steady trend with no noticeable changes during the baseline period.

After the installation of the SM-170 snack miser, the temperatures of the snacks were obtained again and as expected, there were minor fluctuations in the temperatures. The temperature profile in Figure 25 of the snacks in the snack machine show that the temperatures of the snacks ranged from 22.3°C to 23.5°C. (See Appendix E)

Figure 26: Product Temperature Comparison Before & After SM-170 Installation

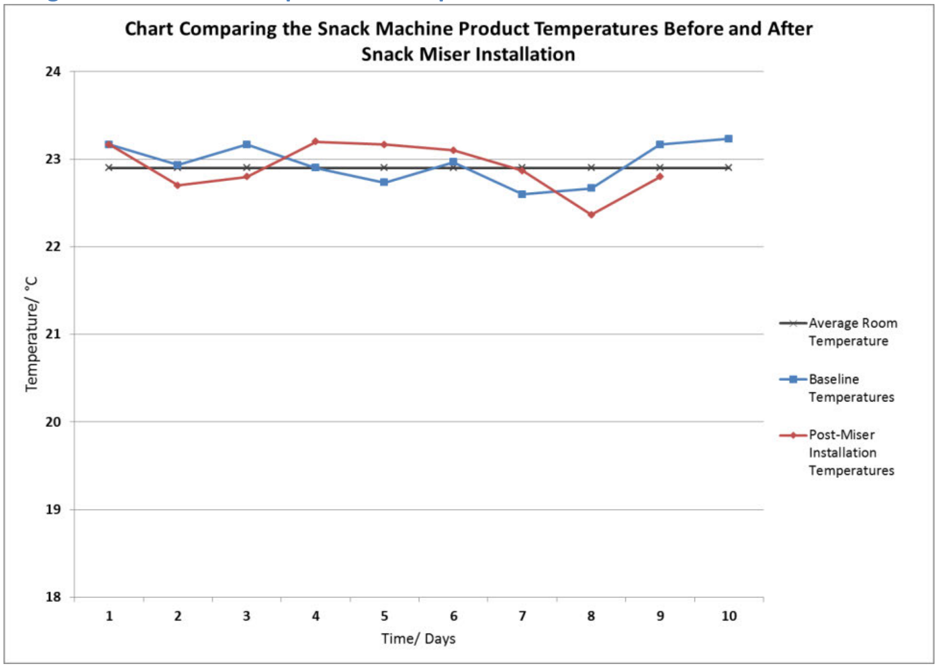


Figure 26 puts the temperature of the snack machine products in perspective when compared to the average room temperature of 22.9°C. Both profiles fluctuate about the mean room temperature, and the calculated difference was 0.0°C. This graph suggests that the snack machine is, in fact, not temperature controlled, as the manufacturer could not verify whether the model under investigation was retrofitted with a temperature control system.

Heating ventilation and air conditioning (HVAC) interactions were not considered in this temperature analysis. However, it should be noted that during the months of summer, when it is usually warm, the energy saved will result in a decrease in energy consumption of cooling equipment (example: electrical centrifugal water chillers). This is because during the energy saving mode of the machines with the misers, less heat will be radiated and dissipated into the environment, thus reducing the amount of cooling necessary. For example, an electric chiller with a coefficient of performance (COP) of 3.0 will save an additional one third of its energy (1/COP) when energy is saved via vending misers.

During the months of winter, when heating is required, the energy saved by the vending misers may be offset by the energy that is consumed by the heating equipment, such as the natural gas boiler or heat pumps. This means that the potential for savings will not be fully realised during the winter months when heat is needed, since the heat radiated by the vending machines will be miniscule, thereby making the building require additional heating.

9.3 Behavioural Analysis

This section deals with the behavioural aspect of the pilot project as it was of interest to observe customer behaviour and interaction with the vending and snack machines in Koerner Library.

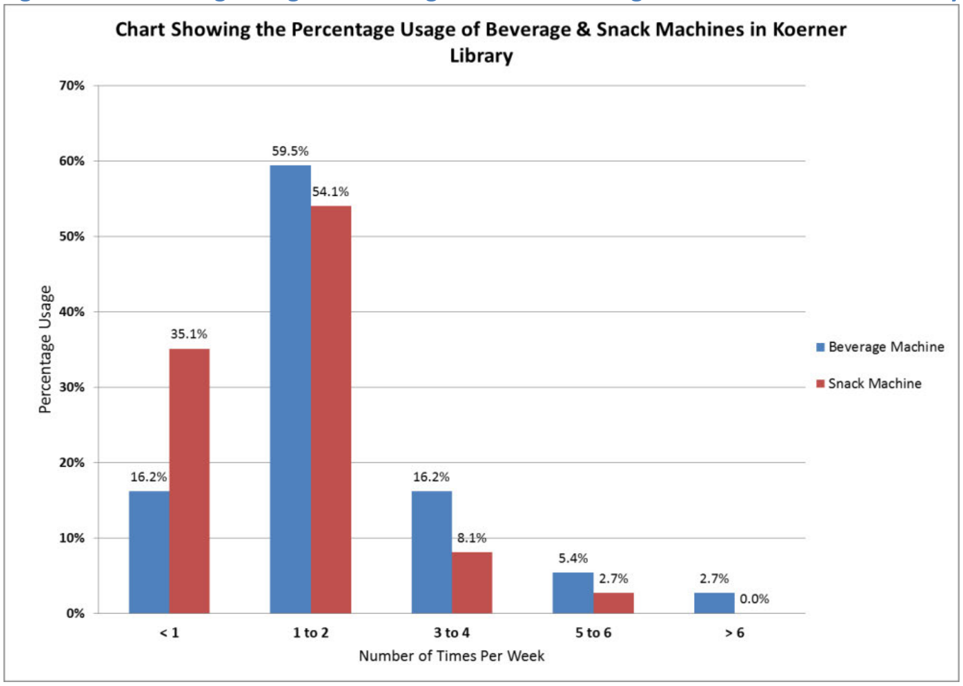
9.3.1 Behavioural Observation

Through personal unobtrusive observation of customers, it was observed that almost all of the customers failed to notice that there was a sensor on top of the snack and beverage vending machines. Attention was more focused on what consumable item options were available through the glass front door of both machines.

9.3.2 Surveys

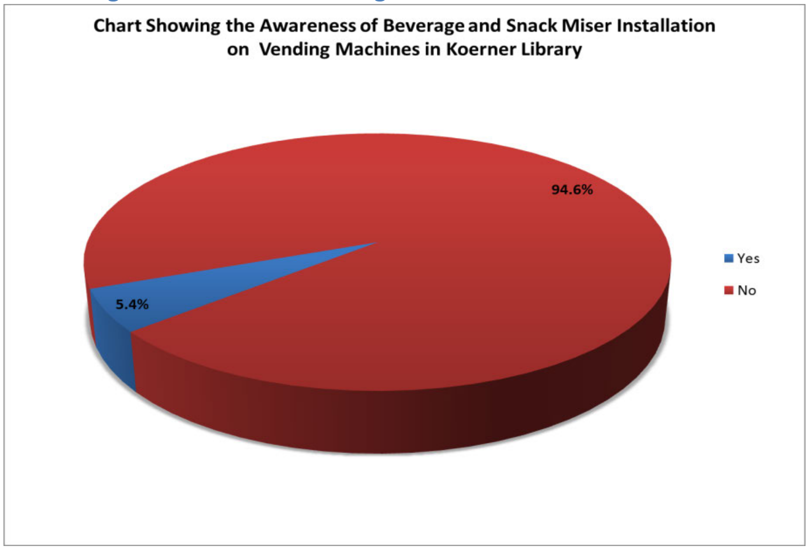
Of the approximately 185 customers who were observed over a period of roughly 35 hours, spread out over 9 days, there were a total of 37 participants in the questionnaires that were issued on site. Observations and surveys happened during a 3-4 hour time span each day. The success rate based on averaging ratio of participants to non-participants was deemed to be approximately 20% which meant that 1 in 5 people, who were asked, participated in the survey.

Figure 27: Percentage Usage of Beverage & Snack Vending Machines in Koerner Library



The frequency of usage of the snack and beverage machines on the second floor in Koerner Library was determined from the questionnaire and is shown in Figure 27. The majority of customers use the beverage and snack machines between 1 to 2 times per week, with a frequency of 59.5% and 54.1% respectively. 16.2% and 35.1% of customers used the beverage and snack machines less than once per week respectively. Only 2.7% of customers used the beverage machine more than 6 times per week with the remaining percentage of customers using the machines between 3 to 6 times per week. This graph may lead one to assume that these machines were not frequented often but it does not take into consideration the 'background traffic' which may constantly activate the PIR sensor system.

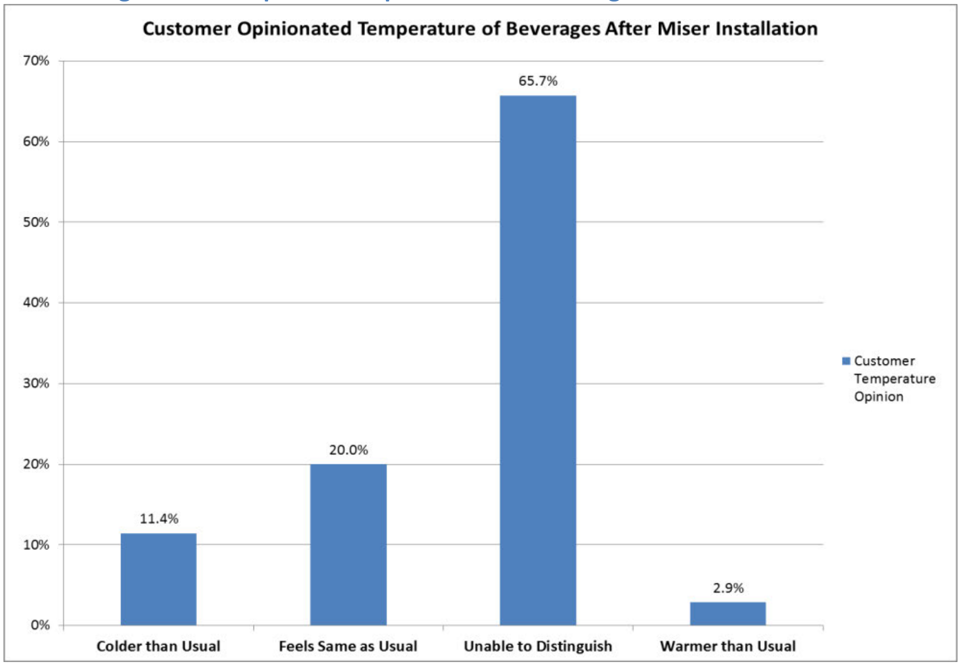
Figure 28: Percentage Awareness of Vending & Snack Misers on Machines in Koerner Library



Responses from the survey indicated that observations of customers' behaviour corresponded with their answers regarding awareness. Figure 28 revealed that 94.6% of participants were not aware that the vending and snack miser system were installed on the respective machines, while 5.4% indicated that they were aware, stating that the sensors with the green lights on top of the machines were noticeable. The actual miser was situated to the back of the vending and snack machines and thus was out of sight, leaving only the mounted PIR sensor visible. Based on observation of the non-participants as well, it can be said that when approaching the machine, most of them did not notice the sensor.

Customer interaction with the vending machines was not negatively affected in any way during occupancy hours since the misers did not allow the machines to be powered down into energy save mode, and as such, the lights remained on in both machines during Koerner opening hours. This is attributed to the fact that the types of misers purchased and installed (VM-170 and SM-170) only powered down the machines when there was zero occupancy detection by the sensors.

Figure 29: Temperature Opinions from Beverage Machine Customers



According to the data represented in Figure 29, a 65.7% majority of respondents indicated that they were unable to distinguish whether the temperature of their drink was either warmer of colder than on previous occasions. Another 20% indicated that the drinks they purchased felt the same temperature as they were usually accustomed to. Only 11.4% indicated that purchased beverages were colder than usual, while 2.9% indicated that the beverages were warmer than usual. The majority of customers were unable to distinguish the 0.6°C increase in temperature, which would be expected for such a small change. Most people distinguish temperatures when there is more than a 2°C change, so even though the beverages were slightly warmer most respondents were unable to notice.

9.4 Pilot Energy Savings

Table 2: Vending & Snack Machine Energy Savings

	Conventional Vending Machine		Energy Star Vending Machine		Snack Machine	
	Baseline	With VM-170	Baseline	With VM-170	Baseline	With SM-170
Average Power Demand (W)	396	233	192	174	55	31
Electricity Consumption (kWh/year)	3,461	2,042	1,682	1,519	484	275
Electricity Savings (kWh/year)	1,419		162		209	
% Electricity Savings	41.0%		9.7%		43.1%	

**Note that the above power values were determined from averages of data points but the energy savings are based on average watts and watt-hours logged by the watt-meter (See Appendix D for sample calculations)*

Based on energy observations and locations of the vending machines, the assumption can be made that the case of the Klinck Building would better represent the upper bound of attainable energy savings on chilled beverage vending machines while the one evaluated in Koerner Library would better represent the lower bound of attainable energy savings. Table 2 shows that energy consumption for the conventional vending machine with the VM-170 installed, was 2,042.1kWh/year which is 41% lower than the baseline of 3,461kWh/year. This percentage was in the typical range (35% - 46%) of the savings obtained in previous studies done on conventional vending machines and indicated that vending misers are, in fact, capable of saving energy.

The baseline data also displayed an average energy consumption of 1681.6kWh/year from the Energy Star machine which is about 49% less than that of the conventional vending machine and conforms to the Energy Star rating where these machines typically consume about 50% less energy than their conventional counterparts. The energy consumption after the vending miser was installed on the Energy Star machine was 1,519.3kWh/year which meant only a 9.7% reduction in energy consumption. This was expected as the vending machine in Koerner Library was one of the newest models of Energy Star machines that were on UBC campus and thus savings would have been minimal.

As can be seen in Table 2, the snack machine in Koerner consumed on average, 484.1kWh/year and this low value is due to the machine being unrefrigerated and equipped with only a fan driven by a motor and an 18W fluorescent lamp. The energy consumption post-installation of the snack miser was 275.3kWh/year and worked out to be a 43.1% reduction in energy usage by that machine. Despite being located in a heavy traffic area, the snack machine showed significant energy savings relative to its baseline consumption. This value is different to the percentage of power saved because as mentioned previously, the average power was used in those scenarios to calculate the power reduction. Both percentage savings however attest to the manufacturer's statement indicating that up to 46% of energy can be saved with snack misers.

Figure 30: Conventional Vending Machine Energy Comparison (With & Without Miser)

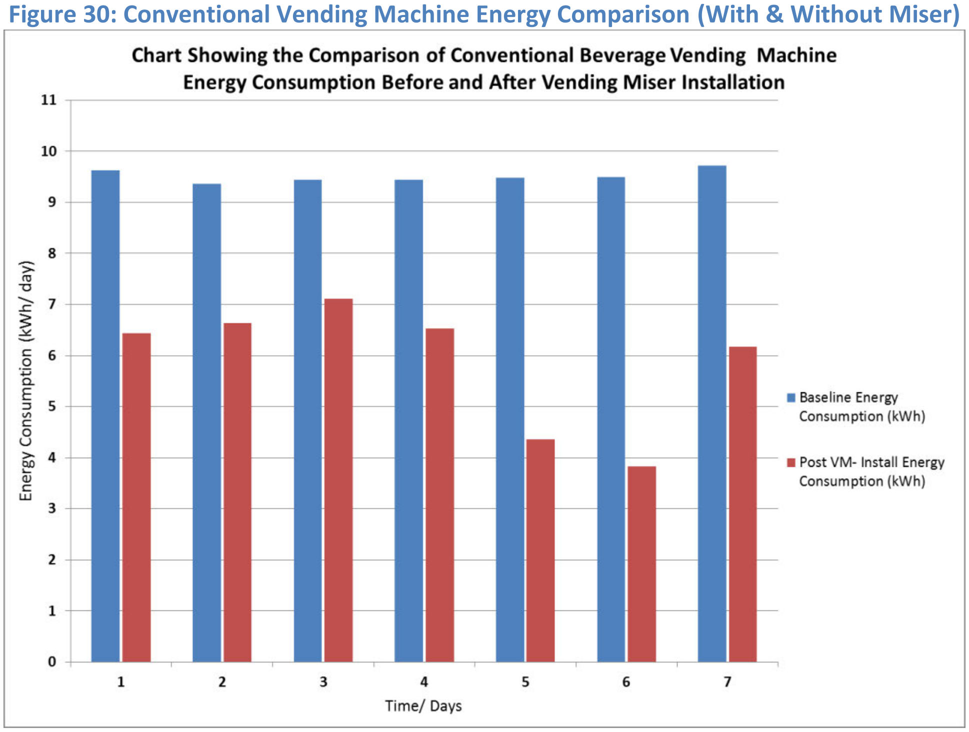


Figure 31: Energy Star Vending Machine Energy Comparison (With & Without Miser)

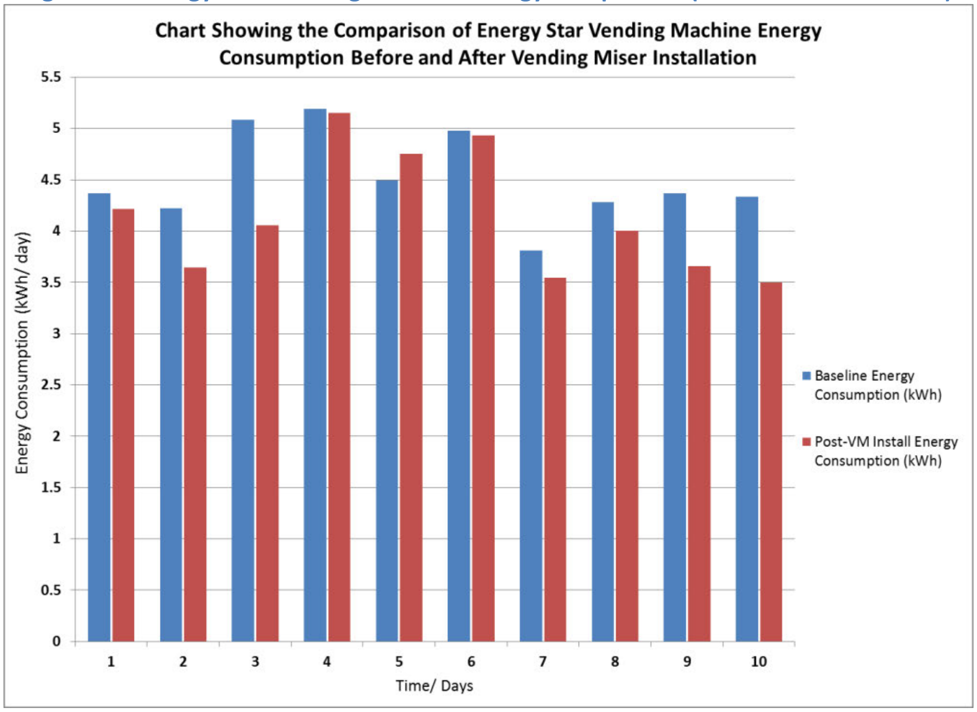


Figure 32: Snack Machine Energy Comparison (With & Without Miser)

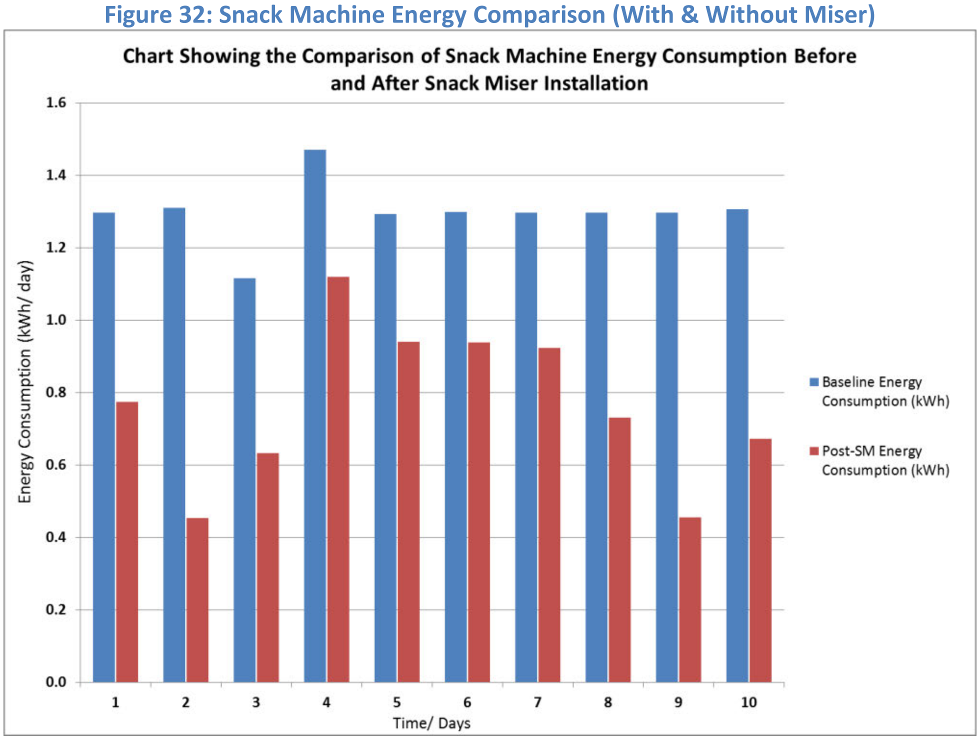


Figure 30 shows the daily electrical consumption for the conventional vending machine during the 7-day baseline and post-miser installation period. The baseline consumption showed minor fluctuations between 9kWh/day and 10kWh/day which can be considered fairly consistent. After the VM-170 miser was installed on the machine, there were evident decreases to daily energy consumption. Day 1 and 7 correlates to Tuesday and Monday respectively and it can be seen that there is a relationship between energy savings and occupancy. Day 5 and 6 which represent Saturday and Sunday, days when the Klinck building is closed, show the least amount of electricity consumed by the vending machine. The consumption during the week is higher than the weekends but relatively consistent. There were savings of 37.5kWh during the 7-day period which represented a 40.8% reduction in energy consumption for this time period.

Figure 31 illustrates the daily electrical consumption for the Energy Star vending machine, with and without the vending miser. Days 1 to 7 represent Saturday to Friday, while Day 10 represents the following Monday over the 10-day measurement period. The baseline and post-miser installed consumption followed a similar pattern with minor decreases per day, with an 8.3% reduction in energy consumption. This indicated that the vending miser was not as effective in reducing energy consumption on the Energy Star vending machine as it was on the conventional vending machine. There is also some suggestion from the shape of the baseline data, that the Energy Star machine also has a mechanism in place, based on frequency of usage to regulate its energy consumption, as both seem to be higher during the week than on weekends.

The daily energy consumption for the snack machine is shown in Figure 32. As in the case of the conventional vending machine, the baseline electrical consumption is relatively steady at about 1.3kWh/day but there is a discernible decrease in consumption after the installation of the SM-170 miser. Days 2 and 9 represent Sundays which show the lowest electrical consumption compared to the other days of the week. This graph is also indicative of the relationship of occupancy hours with snack machine energy consumption which is dictated by the miser and sensor system. 5.34kWh of energy was saved during the 10 day period and worked out to be a 41.1% reduction.

It must be noted that the above savings and Figures 30, 31 and 32 were determined based on data of 'Cumulative Watt-hours' logged by the meter and broken down to an average per day, so these daily graphs along with the savings are not an accurate representation of energy consumption and are thus only served as illustrative representations of energy for the data gathering time periods.

It should be noted that the effect on the peak load from vending misers and snack misers is almost negligible. The power requirements of both the Klinck building and Koerner Library are not affected during times at the highest points of customer electricity consumption, as the vending machines have the same power demand during occupancy hours in the day. Since the majority of energy is saved during non-occupancy hours, this coincides with off-peak hours of electricity consumption. Therefore there is essentially no reduction on peak power demand when vending misers are installed on vending machines. Peak load savings are negligible as the vending machines are often located in occupied areas during the peak demand periods and any minor reduction can be explained by the small timeframes of non-occupancy.

9.5 Pilot Cost Benefit Analysis

The following Table 3 shows the various costs incurred in undertaking the project. The purchase cost of the misers was obtained from the manufacturer[1]. At the time of this pilot project, the rebate was available by BC Hydro but has since been removed from the Power Smart Partner Express incentive program and as such is no longer available. This 'no-rebate' scenario will be used later on in the full scale implementation scenario.

Table 3: Breakdown of Project Costs

Cost Category	Per Vending/Snack Miser Unit
Blended Cost of Electricity[2]	\$0.052/ kWh
Cost of VM-170	\$198.45
Cost of SM-170	\$168.00
Tax	12.00%
Shipping & Handling[3]	\$10.00
BC Hydro Rebate (VM-170 only)[4]	\$134.25
Cost of Installation[5]	\$20.00

A cost benefit analysis was performed on each type of vending machine that was investigated and the results summarised in Table 4 below. See Appendix D for sample calculations.

[1] http://www.vendingmiserstore.com/c153/vending_miser.php
[2] Blended cost is what UBC pays for electricity and factors in monthly demand, taxes and rate riders.
[3] Shipping & Handling was an expedited cost for the shipping of the VM-170 and SM-170 units.
[4] BC Hydro has only offered rebates for vending misers of which the VM-170 falls into the category. There are currently no incentives for snack misers.
[5] Cost of installation was based on \$60/ hour rate and installing 3 misers per hour and takes into consideration time to move the machine, installation and validation of the sensor system.

Table 4: Summary Cost Analysis for Vending & Snack Machines

Vending Machine Type	Conventional	Energy Star	Snack
Annual Energy Consumption Before Miser (kWh)	3,461	1,682	484
Annual Energy Consumption After Miser (kWh)	2,042	1,519	275
Annual Energy Savings (kWh)	1,419	163	209
% Energy Savings	41.0%	9.7%	43.1%
Annual Cost Savings from 1 Miser ($)	$73.77	$8.44	$10.86
Rebate	***Yes***	***Yes***	***No***
Purchase Cost of 1 VM-170 ($)	$98.01	$98.01	$198.16
Installation Cost ($/ Miser)	$20.00	$20.00	$20.00
Annual Cost per kWh Saved ($)	$0.08	$0.67	$1.05
Simple Pay Back Period (years)	1.6	14.0	20.1

Table 4 summarizes the calculations in the preceding sections and includes the cost benefit analysis on the different types of vending machines and the snack machine with the VM-170 and SM-170 installed. The cost savings from one VM-170 miser that would save the operational cost of the conventional vending machine was calculated to be $73.77/year. This is almost 9 times more than that of the Energy Star vending machine, which only saves $8.44/year per miser unit, but is an indication that the vending miser can still squeeze more monetary savings out of an Energy Star rated machine. As such, it will be more financially beneficial if vending misers were installed only on conventional vending machines.

These savings, however, fall short of some previously estimated savings of about $98/year/ unit, according to a news release by the City of Houston[23]. When compared to the study done by the Texas A&M University with cost savings of $64/year/unit, the findings of $73.77/year/unit in this project is greater[15]. The differences in these cost savings could be due to the varied cost of electricity per kWh, the model and capacity of the vending machines and ambient temperatures of their locations. In reference to Table 8, one SM-170 only saves $10.86/year which is also comparatively low to the $50/year which is stated in the sales brochure[24]. The snack misers on the snack machines are too costly for such a lengthy payback period and this is due to the low energy consumption of the unrefrigerated snack machines despite high energy percentage savings.

The rebate offered by BC Hydro was only for vending misers such as the VM-170, however, there was no rebate offered for the SM-170. The rebate of $134.25 for the pilot project, allowed a cost decrease of the VM-170 to $118.01 per unit while the cost of the SM-170 remained at $218.16 per unit. This can be conveyed with the term 'cost per kWh saved per year' which is essentially, the expenditure needed on the miser to save 1 kilowatt of power in the machine each year. Thus, the conventional vending machine has the lowest annual cost per kilowatt-hour saved followed by the Energy Star vending machine and then the snack machine.

Looking at payback period, the most feasible option was that of installing the vending miser on the conventional vending machine, since it carried the smallest payback period of 1.6 years. It can be understood that it is not economically feasible to install vending misers on Energy Star machines as the payback period, even with financial incentives, is too long, and could stretch to more than 14 years. The same can be said about the installation of snack misers on snack machines as the current payback period is 20 years, despite its significant energy reductions.

Table 5: Annualised Costs & Annual Cost of Energy Conserved from Misers

Vending Machine Type	Conventional	Energy Star	Snack
Energy Savings (kWh/year)	1,419	162	209
Persistence (years)	5	5	5
Energy lifetime (kWh)	7095	812	1044
Cost *Without Rebate*/Miser ($)	252.26	252.26	218.16
Annualised Costs[6] ($)	$58.27	$58.27	$50.39
Annual Cost of Energy Conserved ($)	$0.041	$0.359	$0.241
Cost *With Rebate*/Miser ($)	118.01	118.01	No Rebate Offered
Annualised Costs ($)	$27.26	$27.26	-
Annual Cost of Energy Conserved[7] ($)	$0.019	$0.168	-

Table 5 summarises the annual cost of energy that is conserved from each of the misers on their respective vending machine types. The manufacturer's warranty for the misers is 5 years and thus a

[6] Excel Payment function used with a rate of 5%, 5 payment periods, and present value of respective miser costs.
[7] The rebate values were calculated using the 'Goal Seek' function in MS Excel to allow the Annual Cost of Energy Conserved to be equal to $0.13/kWh.

persistency of 5 years is assumed. As expected, the energy lifetime savings are the highest for the conventional vending machine and smallest for the Energy Star machine. The annual cost of energy conserved for the conventional vending machine (without rebate) is the lowest, at $0.041/kWh saved. This means that from an economic savings standpoint, it would be worthwhile to pursue installing vending misers on conventional vending machines as it is less than the $0.052/kWh which UBC pays for electricity and also less than the price of $0.13/kWh that BC Hydro buys power from Independent Power Producers (IPPs).

Thus, from both UBC's and the utility's perspective, the use of vending misers on conventional vending machines is advisable and a case can be made for providing rebates for those misers, since it will prove beneficial to the university. The options of misers (without rebate) on the Energy Star and snack machines are not worthwhile as the annual cost of energy conserved is greater than UBC's blended rate of electricity and also higher than the cost from IPPs.

The rebate that was offered allowed the value of the annual cost of energy conserved of the conventional vending machine to drop to $0.019/kWh conserved which is worthwhile for both UBC and BC Hydro. The rebate offered for misers on Energy Star machines was not enough to make it attractive from a utility perspective, since the annual cost of energy conserved is $0.168 which is still higher than the purchasing price from IPPs. The rebate from BC Hydro needed to bring the annual cost of energy conserved for the Energy Star machine miser to $0.13/kWh was found to be $161.10/miser, while the rebate needed for the snack machine miser was calculated to be $110.54/miser. With these rebates, only then will these options become attractive from UBC's perspective.

Figure 33: Pilot Scale Vending & Snack Miser Energy Savings

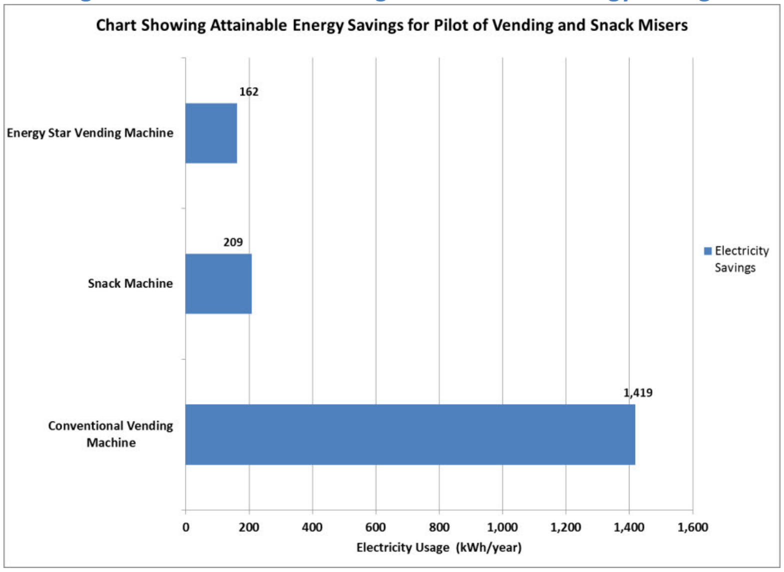


Figure 33 shows a graphical comparison of the energy savings, with conventional vending machines with vending misers installed showing total savings of 1,419kWh/year, followed by snack machines with snack misers installed showing total savings of 209kWh/year. The smallest savings will come from Energy Star vending machines with vending misers installed, having total energy savings of 162kWh/year. The majority (85%) of annual energy savings will come from conventional vending machines, while lesser energy savings from snack machines will account for 12%, with the Energy Star vending machines recording only 3%.

Table 6: Comparison of Energy & Cost Savings of VM-170 with Manufacturer Program Calculations

Conventional Vending Machine	Pilot Project Findings	Manufacturer Excel Program
Energy Consumption –Baseline (kWh/year)	3,461	3,451
Energy Consumption – With VM-170 (kWh/year)	2,042	1,774
Energy Savings (kWh/year)	1,419	1,677
% Energy Savings	41.0%	48.6%
Cost Savings from 1 VM-170 ($/year)	$73.77	$87.23
Simple Pay Back Period (years)	1.6	1.2

Table 7: Comparison of Energy & Cost Savings of SM-170 with Manufacturer Program Calculations

Snack Machine	Pilot Project Findings	Manufacturer Excel Program
Energy Consumption - Baseline (kWh/year)	484	480
Energy Consumption – With SM-170 (kWh/year)	275	246
Energy Savings (kWh/year)	209	234
% Energy Savings	43.1%	48.8%
Cost Savings from 1 SM-170 ($/year)	$10.86	$12.20
Simple Pay Back Period (years)	20.1	17.1

An Excel file created by the manufacturer (http://www.vendingmiserstore.com) of these load managing devices was used to conduct a comparative energy and cost analysis with the findings of this pilot project. The data is given in Tables 6 and 7. It was found that the values for energy savings (kWh/year) for one VM-170 unit installed on the conventional vending machine and the SM-170 snack miser were lower for the pilot project. These values were 1,677kWh/year which represented a 15.4% difference for the VM-170 unit, and 234kWh/year which represented a 10.7% difference for the SM-170 snack miser.

The translated cost savings per miser were also lower for the pilot project, with similar percentage differences. However, the payback periods were higher for the project, showing differences of 0.4 years and 3.0 years respectively.

The differences in both sets of values can be attributed to:

•The number of occupancy hours used in the manufacturer's calculations was based on an average per week, but this may not necessarily be the case. For example, in the Klink building, staff and others with key-cards have access to the building after closing hours which could possibly explain the difference.

•The Excel program which was used by the manufacturer assumed standard times of automatic re-powering of the vending machines, along with an air conditioning factor which may have led to the differences in results.

9.6 Full Scale Implementation Scenario

As mentioned previously (in Section 9.5), the rebate that was offered by BC Hydro is no longer available since vending misers have been removed from their Power Smart Express incentive program. Thus, for this section, no rebate will be assumed. Also, given the analysis of results of the pilot project, only conventional vending machines would be considered. This is the only realistic potential for campus-wide implementation of vending misers, given that UBC will not fund projects for which payback periods are greater than 5 years.

9.6.1 Full Scale Energy & Cost Savings

Table 8: Vending Miser Energy Reductions with Total Cost and Payback Period for Full Scale Scenario

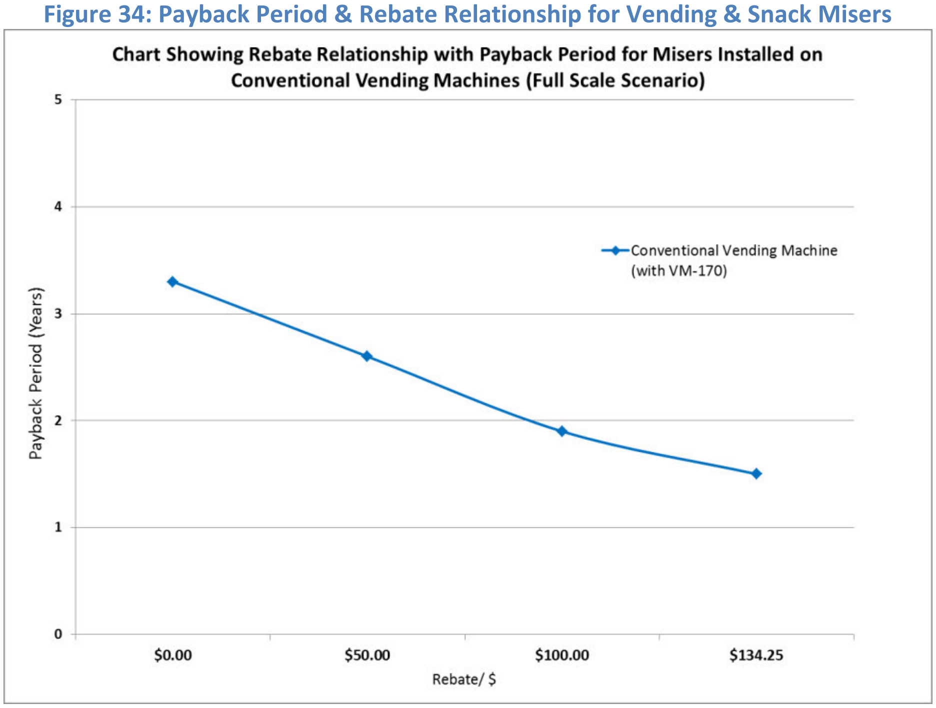
Vending Machine Type (Number)	**Conventional Chilled Beverage** (89)
Total Purchase Cost of VM-170[8] ($)	19,781.14
Total Installation Cost ($/ Miser)	1,780.00
Total Cost of Misers ($)	21,561.14
Total Vending Miser (VM-170) Electricity Savings (kWh/ year)	126,264
Vending Miser (VM-170) Electricity Cost Savings ($/ per year)	6,565.74
Simple Pay Back Period (years)	3.3

Table 8 summarizes the energy and cost savings which can potentially be obtained if there is an installation scale up of vending misers on the conventional machines located on the UBC campus since they have the capability for the greatest amount of energy and cost savings. The total cost of theVM-170 misers would be $21,561.14 and would result in annual cost savings of $6,565.74 which will lead to a payback period of 3.3 years.

[8] Cost for Full Scale Scenario assumes that misers will be delivered via ground shipping thus Shipping & Handling costs are zero. In addition, no rebate is assumed for this scenario therefore cost of one VM-170 is $222.26

The length of the payback period in the full scale implementation differs slightly from the payback period found with the misers purchased for this pilot project. This is because if the misers are ordered in bulk there is a 'free ground shipping' option which will reduce the cost per miser unit, thus, essentially reducing the breakeven period. It should be reiterated that UBC only considers projects with payback periods of 5 years or less and gives greater preference to projects with payback periods of less than 2 years. This scale up falls between the two such time frames.

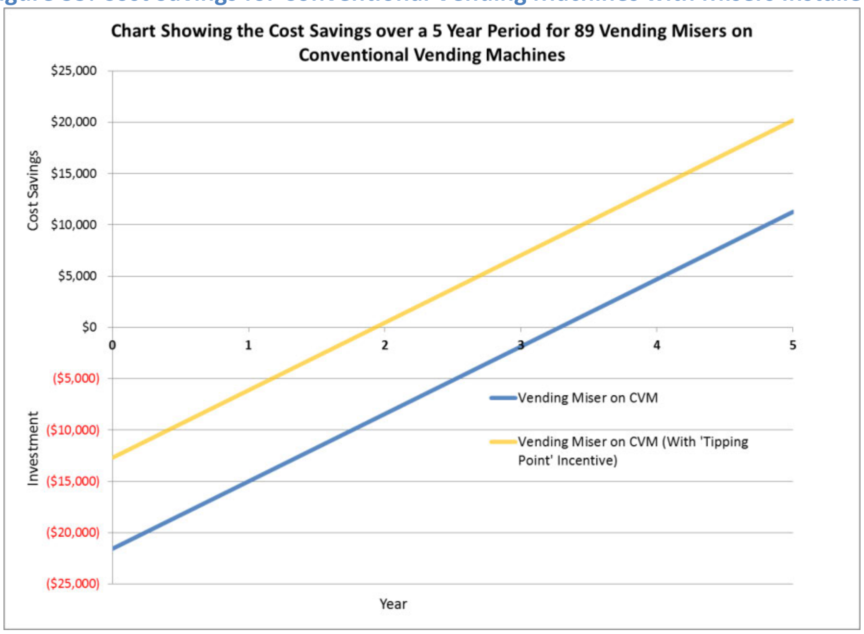
Figure 34: Payback Period & Rebate Relationship for Vending & Snack Misers



The number of years required for the project costs to breakeven in each machine installation is illustrated in Figure 34. The data points show different scenarios of incentive funding and its effect on the payback period. The rebate that was offered by BC Hydro is $134.25 which was applied to the conventional chilled beverage vending machine. The only economically feasible option is the installation of vending misers on conventional energy machines which are non-Energy Star rated. These machines account for 80% of the machines on campus and the current payback period without rebate is 3.3 years.

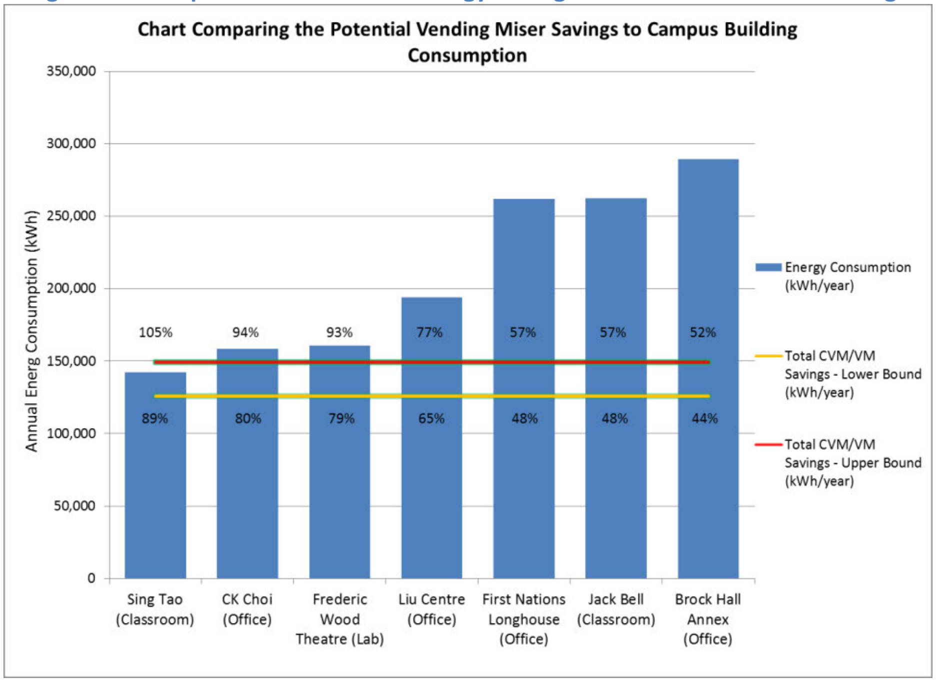
This rebate will not be offered if there is to be full scale implementation of vending misers. However, as previously mentioned, UBC generally gives preference to projects with 2 or less payback years. As can be seen, an incentive of $100/miser will allow full implementation to be favourable, given that this will be the tipping point for project consideration and will improve the project economics.

Figure 35: Cost Savings for Conventional Vending Machines with Misers Installed



Illustrated in Figure 35, is the payback period along with the annual cost savings for the installation of vending misers on the conventional vending machines only. The scenario over a five year period does not incorporate a rebate provided by BC Hydro since this is no longer available. The cost savings after 5 years would be an estimated $11,268. Also included is the 'tipping point' of the financial incentive needed to reduce the payback period to less than 2 years, which as mentioned before, was $100/miser. This will mean a reduced capital investment of $12,661 and cost savings of $20,168 after a 5-year period. These monetary savings represent an average, and may be less or more depending on occupancy and power requirements of the vending machines.

Figure 36: Perspective of Potential Energy Savings in Relation to UBC's Buildings



In reference to the 'Manufacturer Excel Program ' column in Table 6, the estimated energy savings for the 89 conventional vending machines on campus will be approximately 149,253kWh/year. For the purposes of this report, that value will represent the upper bounds of the attainable energy savings, while the actual findings of 126,264kWh/year in energy savings will be representative of the lower bound.

The buildings on UBC campus with annual energy consumptions of less than 300,000kWh are shown in Figure 36. It also shows the 149,253kWh/year upper bound and 126,264kWh/year lower bound line that represents the total energy saved from installing vending misers on conventional vending machines. The chart shows the percent of energy which the buildings will no longer have to utilize.

For example, the vending miser energy savings can cover between 89% to 100% of the annual energy requirements of the Sing Tao classroom and 44% to 52% of the energy requirements of Brock Hall Annex office. This puts into perspective how much the potential savings are worth and what can be achieved, as it is almost equivalent to shutting down an entire building such as Sing Tao or CK Choi. These savings are also equivalent to approximately shutting down half of the First Nations Longhouse or Jack Bell.

9.6.2 Full Scale Emission Reductions

Greenhouse gas (GHG) emission data was obtained from Environment Canada which cited the *Canada's National Inventory Report: 1990-2009*. The greenhouse gas emission intensity data for the generation of electricity in the province of British Columbia is provided below for the year 2009.

Greenhouse Gas Intensity: 25 g CO_2 equivalent/kWh electricity generated[25]

Table 9 below summarizes the carbon dioxide equivalent emission reductions, given a full scale implementation scenario of the 89 vending misers on the conventional vending machines on UBC campus.

Table 9: Full Scale Vending Miser Greenhouse Gas Emission Reductions

Conventional Vending Machines	
Total Vending Miser (VM-170) Electricity Savings (kWh/ year)	126,264
Greenhouse Gas Emission Savings (kg CO_2 equiv/ year)	3,157

It can be seen that the total yearly GHG emission reductions could potentially be in the vicinity of 3,157 kg CO_2 equivalent and that the conventional vending machines will account for savings equivalent to 35.3 kg CO_2 equivalent/ year/ machine. This is almost equivalent to reducing the emissions of an average light duty vehicle with an internal combustion engine that makes a return trip from Vancouver to Halifax every year[9]. Put in context, this is not very significant as most of the electricity in British Columbia is considered clean and GHG emissions from electricity only account for about 8% while steam and gas usage by buildings which has much higher emission factor than electricity, account for 89% of GHG emissions.

[9] Average CO_2 equivalent emissions of a typical ICE Light Duty Vehicle: 0.205kg/km. Road distance from Vancouver to Halifax: 6140km.

9.7 Limitations

There were several limitations with this project which may have had potential impact on the findings. One of the main limitations, as mentioned earlier in the report, was the lack of peer reviewed literature to compare data and results. There were many independent and private third party organisations which conducted previous research but the accuracy of their findings varied.

There were also limitations of access to the initial project location which led to the investigation of vending machines elsewhere on campus. The original location in Green College was not feasible due to the inaccessible electrical outlets which meant that the vending and snack machines would have had to be emptied and moved which was impractical. Along with this was issue was the lack of overhead space on top the machine for sensor placement.

Another limitation encountered was related to time constraints to complete data logging on the conventional machine. As the project progressed, it was recognised that the initial chilled beverage machine was an Energy Star rated machine and only accounted for 20% of machines on campus so sample data from the 80% of unconventional machines was required. However this could only be done over a 14 day period rather than a 20 day period due to the time needed to interpret and compare results. The issue of time was also the reason of the inability to do comparative measurements of vending machines in other buildings elsewhere on campus.

Timing for behavioural assessment should have taken place at different times since there was the inability to observe people's reaction at the beginning of opening hours of the library. Graphed data showed that someone (more than likely staff) would have to set off the motion sensor as the library opened, thus activating the lights and refrigeration system in the case of the vending machine, and the lights and fan in the case of the snack machine.

Another constraint was the sample size of 37 customers who took part in the survey; this may have been too small to find significant relationships from the data which generally requires a larger sample size for a proper representation of the distribution of people. However, based on personal judgment, the sample size was sufficient for the scope and purposes of this project.

10.0 Conclusions & Significance of Project

This pilot project proved successful in representing and evaluating the different types of vending machines and was helpful in determining the potential amount of energy savings that can be achieved from these vending machines on the UBC Campus. The results and findings have led to the following conclusions:

1) The vending and snack miser performed as expected when installed on the conventional vending machine and snack machine, exhibiting energy savings of 41.0% and 43.1% respectively, but did not perform as well on the Energy Star rated vending machine that only showed savings of 9.7%.

2) Cost-benefit analysis determined that conventional machines were best suitable for vending misers to be installed on those machines, since the Energy Star rated vending machine and snack machine were not economically feasible.

3) Given the present situation where the BC Hydro rebate is being no longer available, the vending misers should only be installed on UBC's 89 conventional vending machines. If there is to be full scale implementation at a total cost of $21,562, then:
    a. The total yearly energy savings would be approximately 126,264 kWh
    b. The total annual cost savings would be approximately $6,565.74 ($73.77/miser/year)
    c. The payback period would be 3.3 years
    d. The total yearly GHG emission reductions could potentially be in the vicinity of 3,157 kg CO_2 equivalent

4) UBC only considers projects with payback periods of less than 5 years and gives greater preference to projects with payback periods of less than 2 years. Thus, the necessary rebate needed to reduce the payback period to the generally accepted 2 year period for consideration of projects by UBC is $100/ miser.

5) The temperature of the chilled beverages showed an average increase of 0.6°C after the vending miser was installed on the Energy Star rated vending machine on the second level in Koerner Library. Despite this, only 2.9% of survey respondents reported an increase in temperature of their beverage compared to the 65.7% who were unable to distinguish any change.

6) An educational campaign is not deemed to be necessary from the survey feedback since 94.6% of customers were not aware that the load managing device (vending and snack miser with PIR sensor) was installed on the machines. Instead, it should be geared towards the different machine vendors as to inform them of the benefits and non-risk of sales and advertising decline.

10.1 Recommendations for Full Scale Scenario

- The vending machines that were the subject of this pilot project are those managed by SHHS, but there should be inquiries as to whether there are other bodies, for example, AMS and some undergraduate clubs, which also manage vending machines.

- There may be little incentive for individual departments in UBC to have the vending misers installed on the machines since the cost savings usually go to UBC Utilities. Therefore, there should be some investigation into the different funding options that might be available. Possibly, the Centre for Interactive Research on Sustainability (CIRS) or SHHS could fund the project and with an agreement of refund by UBC Utilities.

- Discussions on the logistics should take place between the different vendors who are responsible for the machines on the UBC campus. There should be proper co-ordination of the installation with those responsible for adding, replacing and moving vending machines. If necessary, an education campaign should be launched on the use of misers and emphasis should be made that the devices will not cause the chilled beverages to be warmer or negatively affect their advertising on the machines. Lastly, a process plan should be developed identifying how problems and repairs should be reported, if or when they arise.

- It would be worthwhile to consider the rate increase of electricity slated for the next few years, as any rise in the cost of electricity will help in the case for implementing vending misers on the conventional vending machines. In the next fiscal year, the rate is expected to increase from $0.052/kWh to $0.054/kWh, which represents a 3.7% increase.

11.0 Recommendations for Future Work

A sensitivity analysis should be performed to determine what buildings will be best suited for installing these load managing devices. Buildings with low occupancy hours should be evaluated and matched with conventional machines to ensure higher energy savings. This will provide economic justification and smaller payback periods, thus maximising savings.

The sensitivity analysis should include whether or not there is sufficient overhead space above the vending machines for the placement of the sensor. If not the VM-150 model will have to be purchased as the sensor has wall mounted capabilities. In instances where there are a number of machines located within proximity of each other (for example in SUB), the VM-171 models with repeater cords could be purchased. These misers are about $8.40 less than the VM-170 models but do not come with a sensor are they are deemed 'slave' units which connect to the 'master' unit with the sensor installed. This can be an additional cost benefit.

It should be determined whether it will be cheaper to upgrade conventional machines to Energy Star machines or if it would be simpler to install the vending misers on them. There may be some boundaries to this as the machines are not owned by UBC so the cost will be incurred by the vendors and it may be difficult to get the vendors to ensure that all of their chilled beverage machines on campus are Energy Star rated.

Another alternative that should be considered in the future is arrangement to upgrade the lighting in the conventional vending machines to more efficient bulbs or having them completely removed altogether. This can be done since the lighting system is independent of the other electronic systems and will not affect the functionality of the machine. However, the issue with this will be concern by the vendors of a negative impact on advertising and possible sales reduction from those machines.

12.0 References

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13.0 Appendices

13.1 Appendix A – Watts Up? Pro ES Specifications

120 V, 60 Hz, 15 Amps

Memory storage depends on how many parameters are stored, and in what mode the memory is in. 120,000 records is possible in stop/overwrite mode, and when only logging watts. In automatic mode with all parameters recorded the storage is approximately 4000 records.

Higher ratings of 100-250v, 50/60Hz, and 15 amps require the universal outlet (UO) version. The electronics in the meter are capable of 20 amps but the cord and receptacle have different ratings. **Accuracy:** +/- 1.5%, + 3 counts of the displayed value. For loads less than 60 watts, the current and power factor displays will have lower accuracy. However, the wattage and other displays will still be within 1.5%.

USB interface

Mains supply voltage fluctuations not to exceed +/- 10% of the nominal voltage

Rate can be entered from $0.001 to $85.00 per kilowatt hour, in tenths of a penny

Input is via 6' electric cord (USA style only), output is via outlet on top of meter

Indoor use only

Dimensions: 7" x 4" x 2" (18cm x 10cm x 5cm)

Weight: 1.5 lbs. (0.7 kg)

UL listed to standard UL 610010-1, and CAN CAS/C22.2 61010-1

UL certification requires the following statement:

Altitude up to 2000 meters

Temperature 5 °C to 40 °C

Maximum relative humidity 80% for temperatures up to 31°C decreasing linearly to 50% relative humidity at 40°C

Measures and records 18 parameters, including: Current Watts, Minimum Watts, Maximum Watts, Power Factor, Volt Amp (apparent PWR), Cumulative Watt Hours, Average Monthly Kwh, Elapsed Time, Duty Cycle, Frequency (Hz), Cumulative Cost, Average Monthly $, Line Voltage, Minimum Volts, Maximum Volts, Current Amps, Minimum Amps, Maximum Amps.

13.2 Appendix B – Vending Miser & Snack Miser Specifications

VendingMiser (VM-170) Technical Specifications

Electrical Specifications
Input Voltage: 115 Volts
Input Frequency: 50/60 Hz
Maximum Load: 12 Amps (Steady-State)
Maximum Load: 1050 Watts (Steady-State)
Power Consumption: Less than 1 Watt (Standby)

Environmental Specifications
Operating Temp: -15 °C to 75 °C
Storage Temp: - 40 °C to 85 °C
Relative Humidity: 95% Maximum (Non-Condensing)

Compatibility
Vending Machines: Any machine, except those containing perishable goods such as dairy products.

Inactivity Timeouts
Occupancy Timeout: 15 Minutes
Auto Re-power: 1 to 3 hours, dynamically adjusted, based on ambient temperature.

SnackMiser (SM-170) Technical Specifications

Electrical Specifications
Input Voltage: 115 Volts
Input Frequency: 50/60 Hz
Maximum Load: 12 Amps (Steady-State)
Maximum Load: 1050 Watts (Steady-State)
Power Consumption: Less than 1 Watt (Standby)

Environmental Specifications
Operating Temp: 0 °C to 50 °C
Storage Temp: - 20 °C to 60 °C
Relative Humidity: 95% Maximum (Non-Condensing)

Compatibility
Snack Vending Machines: Any type

Inactivity Timeouts
Occupancy Timeout: 15 Minutes

13.3 Appendix C – Vending & Snack Miser Survey

<u>Questionnaire</u>

Hey! You there! Do you have a few minutes to spare? If so, I would greatly appreciate if you would help me with my research project by filling out this survey. There are eight (8) questions, and should not take more than three (3) minutes to complete.

For those who need a little more info on me, I am a Masters student currently pursing Clean Energy Engineering, right here at UBC. Your feedback would allow me to assess whether an education campaign regarding vending misers is necessary and if so, to what degree. ***Vending misers are energy management devices that can be installed onto vending machines, which allow the machines to determine when persons are not in the surrounding area and shut off to save energy.***

Your responses are anonymous and confidential, and all questions are optional! Thank you ☺

1) What do you like most about vending (beverage & snack) machines?
□ convenience □ beverage/snack variety □ other

If other, please state: ____

2) How many times per week, on average, do you use *beverage vending machines*?

□ zero □ 1- 2 times □ 3- 4 times □ 5-6 times □ 7-8 times □>8 times

3) How many times per week, on average, do you use *snack vending machines*?

□ zero □ 1- 2 times □ 3- 4 times □ 5-6 times □ 7-8 times □>8 times

4) How satisfied are you with your experiences using the vending machines on the 2^{nd} Floor of the Walter C. Koerner Library?
□ highly satisfied □ satisfied □ neutral □ dissatisfied □ highly dissatisfied

5) Are you aware that vending misers are installed in the two (2) of these vending machines?
□ yes □ no

6) Have you experienced any problems with the beverage or snack vending machines since Friday 2^{nd} November -date of installation?
□ yes □ no

If 'yes' please briefly indicate: ____

7) In your opinion, the temperature of the beverage(s) you purchased from the vending machine after Friday 2^{nd} November is:
□ colder than usual □ warmer than usual
□ the same temperature □ unable to distinguish

8) Based on your feedback from Question 7, do you believe vending misers should be installed in all vending machines on the UBC campus?
□ yes □ no □ maybe

If 'no' or 'maybe', please state why: ___________________________________

Comments:
____
____

Thank you for your participation in this survey

13.4 Appendix D – Sample Calculations

Vending Machine & Vending Miser Calculations

1 year = 12 months = 365.24 days = 8765.81 hours

111 Operational Vending Machines on UBC Campus (20% are Energy Star, 80% are Conventional)

88 Operational Snack Machines on UBC Campus

Table Displaying Data from *Watts Up? ES Pro Meter*

Watt-Meter Data	Baseline Time (Days)	Average Power (W)	Cumulative Watt-Hours	Post-Miser Time (Days)	Average Power (W)	Cumulative Watt-Hours
Conventional Vending Machine	6.992	395.451	66140.300	6.706	233.1646	37457.900
Energy Star Vending Machine	9.825	192.260	45133.700	10.990	173.580	45653.700
Unrefrigerated Snack Machine	9.826	55.399	12982.100	10.003	30.958	7647.500

Calculations performed are a sample for Table 7. The same method was used for Tables 6 and 8 in the report

Section 1

<u>Conventional Beverage Machine – Baseline Calculations</u>

Average Power Consumption (from *Watts Up? ES Pro Meter*) = 395.451W = 0.395451kW

Annual Energy Consumption = $0.395451\ kW\ \times 8765.81\frac{hrs}{yr} = 3466.45\frac{kWh}{yr}$

Cumulative Watt-hours for 6.992 days (from *Watts Up? ES Pro Meter*) = 66140.3Wh = 66.1403kWh

Cumulative Watt-hours for 1 day = $\frac{66.1403\ kWh}{6.992\ days} = 9.459\frac{kWh}{day}$

Annual Energy Consumption = $9.459\frac{kWh}{day} \times 365.24\frac{days}{yr} = 3454.96\frac{kWh}{yr}$

Average Annual Energy Consumption = $\left(\frac{3466.45\frac{\text{kWh}}{\text{yr}} + 3454.96\frac{\text{kWh}}{\text{yr}}}{2}\right) = 3460.796\frac{\text{kWh}}{\text{yr}}$

Conventional Beverage Machine – Vending Miser Calculations

Average Power Consumption (from *Watts Up? ES Pro Meter*) = 233.1646W = 0.233165kW

Annual Energy Consumption = $0.233165\ kW\ \times 8765.81 \frac{hrs}{yr} = 2043.877 \frac{kWh}{yr}$

Cumulative Watt-hours for 6.706 days (from *Watts Up? ES Pro Meter*) = 37457.9Wh = 37.4579kW

Cumulative Watt-hours for 1 day = $\frac{37.4579\ kW}{6.706\ days} = 5.5857 \frac{kW}{day}$

Annual Energy Consumption = $5.5857 \frac{kW}{day}\ \times 365.24 \frac{days}{yr} = 2040.132 \frac{kWh}{yr}$

Average Annual Energy Consumption = $\left(\frac{2043.877 \frac{kWh}{yr} + 2040.132 \frac{kWh}{yr}}{2}\right) = 2042.077 \frac{\mathrm{kWh}}{\mathrm{yr}}$

Energy Savings Calculations

Savings for **one (1)** vending miser: VM-170 = Baseline Energy – Vending Miser Energy

= $3460.796 \frac{\mathrm{kWh}}{\mathrm{yr}} - 2042.077 \frac{\mathrm{kWh}}{\mathrm{yr}}$

= $1418.70 \frac{\mathrm{kWh}}{\mathrm{yr}}$

Percentage Energy Savings = $\left(\frac{1418.70\ kWh/yr}{3460.796\ kWh/yr}\right) = 40.99\%$

80% of Vending Machines in UBC are Conventional, therefore = $(80\%\ \times 111) = 89$ CVM machines

Estimated Energy Savings for All **89** Conventional Machines = $89\ \times 1418.70 \frac{\mathrm{kWh}}{\mathrm{yr}} = 126{,}264.3 \frac{\mathrm{kWh}}{\mathrm{yr}}$

Section 2

Cost Benefit Calculations

Cost of Vending Miser, VM-170	= \$198.45/ miser
Cost of Snack Miser, SM-170	= \$168.00/ miser
Tax	= 12%
Cost of Shipping & Handling	= \$10.00/ miser
BC Hydro Rebate (*vending miser only*)	= - \$134.25/ miser
Cost of Installation	= \$20/ miser
UBC's Blended Cost of Electricity	= \$0.052/ kWh

Estimated Cost Savings for *1 Conventional Vending Machine*: $1418.70\,\frac{\text{kWh}}{\text{yr}} \times \$0.052/kWh = \$73.77/year$

Estimated Cost Savings for *89 Energy Star Vending Machine* $= \frac{\$73.77}{year} \times 89 = \$6{,}565.53/\text{year}$

With Rebate (Pilot)

Total Cost of 1 Vending Miser = $(\$198.45\ \times 1.12) + \$10.00 - \$134.25 + \$20 = \$118.01/$ miser

Cost per kWh Saved per year = $\left(\frac{\$118.01/\text{miser}}{1418.7\ kWh/yr}\right)$ =\$0.10/kWh Saved annually

Simple Payback Period = $\left(\frac{\$118.01/\text{miser}}{\$73.77/year}\right) = 1.6\ years$

Without Rebate (Full Scale)

Total Cost of 1 Vending Miser = $(\$198.45\ \times 1.12) + \$20.00 = \$242.26/$ miser

Cost per kWh Saved per year = $\left(\frac{\$242.26/\text{miser}}{1418.7\ kWh/yr}\right)$ =\$0.17/kWh Saved annually

Simple Payback Period = $\left(\frac{\$242.26/\text{miser}}{\$73.77/year}\right) = 3.3\ years$

13.5 Appendix E – Energy Star Vending Machine & Snack Machine Temperature Data

Energy Star Vending Machine: Internal Product Temperature (Without Vending Miser)

Day		Beverage Temperature (°C)					
		1st Tray	2nd Tray	3rd Tray	4th Tray	5th Tray	Average
1	Saturday 20th Oct	2.7	2.7	2.7	2.6	2.5	2.6
2	Sunday 21st Oct	2.2	1.8	2.1	1.6	2.1	2.0
3	Monday 22nd Oct	2.6	2.4	2.2	2.9	2.9	2.6
4	Tuesday 23rd Oct	2.2	2.4	1.6	1.8	2.5	2.1
5	Wednesday 24th Oct	2.1	1.9	2.6	2.7	2.2	2.3
6	Thursday 25th Oct	2.4	2.5	2.6	2.8	2.3	2.5
7	Friday 26th Oct	2.6	2.0	2.2	2.2	2.0	2.2
8	Saturday 27th Oct	2.7	2.1	2.0	2.1	2.0	2.2
9	Sunday 28th Oct	1.8	1.5	1.6	1.3	1.8	1.6
10	Monday 29th Oct	2.5	2.3	2.4	2.0	2.1	2.3
Average Daily Room Temperature: 22.9°C							

Energy Star Vending Machine: Internal Product Temperature (With Vending Miser)

Day		Beverage Temperature (°C)					
		1st Tray	2nd Tray	3rd Tray	4th Tray	5th Tray	Average
1	Saturday 3rd Nov	3.0	2.8	2.7	3.0	2.8	2.9
2	Sunday 4th Nov	2.4	2.6	2.3	2.4	2.5	2.4
3	Monday 5th Nov	2.7	2.8	2.9	3.3	3.4	3.0
4	Tuesday 6th Nov	3.1	3.0	2.8	3.3	3.5	3.1
5	Wednesday 7th Nov	3.1	2.8	2.9	2.7	3.2	2.9
6	Thursday 8th Nov	3.0	2.8	3.2	3.1	3.0	3.0
7	Friday 9th Nov	2.5	2.6	3.0	2.7	2.8	2.7
8	Saturday 10th Nov	2.6	2.5	2.8	2.7	2.6	2.6
9	Sunday 11th Nov	2.3	2.1	2.3	-	2.5	2.3
10	Monday 12th Nov	-	-	-	-	-	
Average Daily Room Temperature: 22.9°C							

The differences of the daily tray temperature averages of both tables were found and the average of those values was then calculated to be 0.6°C.

Snack Machine: Snack Product Temperature (Without Snack Miser)

Day		Snack Temperature (°C)			
		Top Tray	Middle Tray	Bottom Tray	Average
1	Saturday 20th Oct	23.2	23.2	23.1	23.2
2	Sunday 21st Oct	22.8	23.1	22.9	22.9
3	Monday 22nd Oct	23.2	23.2	23.1	23.2
4	Tuesday 23rd Oct	23.1	22.8	22.8	22.9
5	Wednesday 24th Oct	22.8	22.7	22.7	22.7
6	Thursday 25th Oct	23	23.1	22.8	23.0
7	Friday 26th Oct	22.6	22.7	22.5	22.6
8	Saturday 27th Oct	22.8	22.5	22.7	22.7
9	Sunday 28th Oct	23.2	23.1	23.2	23.2
10	Monday 29th Oct	23.2	23.3	23.2	23.2
Average Daily Room Temperature: 22.9°C					

Snack Machine: Snack Product Temperature (With Snack Miser)

Day		Snack Temperature (°C)			
		Top Tray	Middle Tray	Bottom Tray	Average
1	Saturday 3rd Nov	23.1	23.2	23.2	23.2
2	Sunday 4th Nov	22.7	22.6	22.8	22.7
3	Monday 5th Nov	22.5	22.8	23.1	22.8
4	Tuesday 6th Nov	23.5	23.3	22.8	23.2
5	Wednesday 7th Nov	22.8	23.2	23.5	23.2
6	Thursday 8th Nov	23.1	23	23.2	23.1
7	Friday 9th Nov	22.8	22.7	23.1	22.9
8	Saturday 10th Nov	22.3	22.4	22.4	22.4
9	Sunday 11th Nov	22.8	22.8	22.8	22.8
10	Monday 12th Nov	-	-	-	-
Average Daily Room Temperature: 22.9°C					

The differences of the daily tray temperature averages of both tables were found and the average of those values was then calculated to be 0.0°C.