UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Electrical Energy Conservation Opportunities for Plug Loads and Lighting in UBC Office Buildings

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SUMMARY

The objectives of this study are to identify no-cost/low cost energy conservation measures regarding plug load and lighting for two UBC office buildings (General Services and Administration Building and Brock Hall) and to qualify the potential impacts of selected measures through tests on electrical energy consumptions.

Based on the information that was gathered by literature reviews, subject buildings' visits, interviews, online monitoring systems, and consultation with Power Smart experts, Campus Sustainability Office staff, a list of energy conservation measures were proposed, as well as the estimations of potential energy savings, simple payback period and cost effectiveness of savings (as dollar investment per kWh saved by dividing Net Present Value (NPV) by lifetime kWh saved) upon each proposed measure.

Furthermore, on-site tests and multiple after-hours site inspections were conducted in order to qualify the actual impacts of two plug load energy conservation measures, and provide more insight information for energy conservation measures on lighting.

1.0 INTRODUCTION

UBC staff and faculty are interested in identifying, researching and implementing no-cost and low cost measures to conserve resources at UBC-Vancouver. Two high level strategic plans-UBC's Climate Action Plan and the UBC Sustainability Academic Strategy-identify the development and enhancement of behavior change programming on campus as immediate actions to take to conserve energy and other resources at UBC-V.

Lighting has always been considered as one of the biggest contributor to electricity consumption for buildings. Although the lighting system of nearly 120 UBC's core buildings including two test sites in this study has been retrofitted by UBC Eco Trek projects, extra energy savings on lighting system still could be achieved by utilizing more centralized control system, improving occupants' behaviors and installing new energy saving products, etc.

While all previous studies have traditionally targeted the HVAC and lighting systems as the best way to reduce the energy consumption, managing office plug loads also has the potential to significantly save the electricity consumption as well.

In the Annual Energy Outlook 2009, the Energy Information Administration (EIA) estimated that the percentage of annual growth from 2007 to 2030 of the office equipment (PC) is about 1.3 percent, which is the fourth fastest growing energy end use for the commercial sector. The energy consumption for other non-PC electric office equipment is expected to grow about 3 percent each year through 2030, which is the fastest growing commercial sector energy end use. (The second and third fastest growing end uses are miscellaneous uses and ventilation respectively) (See APPENDIX A for detailed consumption data). Figure 1 shows the actual and predicted energy consumption by office equipment (PC and non-PC) 2007-2030.

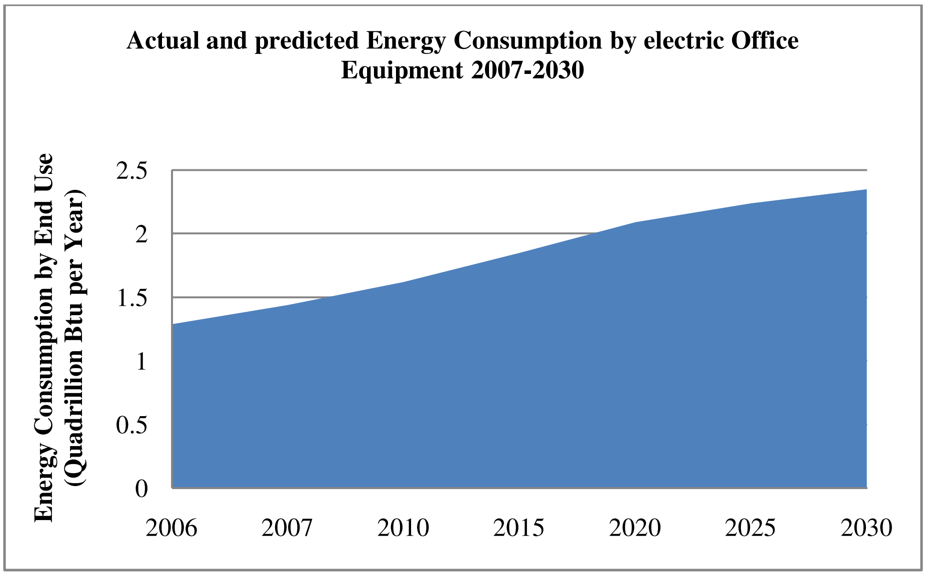


Figure 1: Commercial Sector Actual and Predicted Annual energy consumption by Office Equipment (PC). (Energy Information Administration, 2009)

1.1 Overall Purpose

This project has two objectives: (1) to identify conservation measures (no-cost/low cost) at UBC-Vancouver that have either a high potential impact on energy consumption and/or a greater probability of adoption by building occupants and; (2) to quantify and obtain actual measurement data of the potential impact of selected measures through a series of building energy tests regarding lighting and plug loads.

1.2 Scope of this project

Possible energy saving interventions regarding lighting and plug load, and actual impacts on building energy management by using two office buildings (Brock Hall and General Services and Administration Building) as test sites.

1.3 Methodology

Literature reviews, consultation with Power Smart experts, Campus Sustainability Office staff and sites inspections to identify the possible energy saving, building energy tests and measurements by using real-time monitoring software (the Pulse System), and sub metering tools (Kill-a-Watt meters) to quantify the impacts.

1.4 Resources:

Lillian Zaremba of UBC Campus Sustainability Office as Technical Assistance

Kara Bowen of UBC Campus Sustainability Office as Building Test Coordinator

David Rogers of Power Smart as "Project Sponsor" on technological aspects of plug load management

Alvin Wai of Power Smart as "Project Sponsor" on technological aspects of lighting load management

2.0 LITERATURE REVIEWS

2.1 Plug Load

A plug load is the energy consumed by any electronic device that is plugged into a socket. In offices, plug-load equipments usually include computers, monitors, printers, photocopiers, task lights, etc. Most of them consume electric energy in stand-by mode or even when they are shut down. Therefore, there are big opportunities to reduce the energy consumption.

Of all the potential energy saving opportunities, computers and monitors account for about 70% of total energy savings opportunities for plug-load equipments in campus environment (Sabo, Andrews, Lee, & Bakalars, 2007), therefore, reducing the energy consumption by computers and monitors become the key target of plug load energy-saving measures.

Figure 3 shows the breakdown of the potential savings opportunities by type of plug-load equipments.

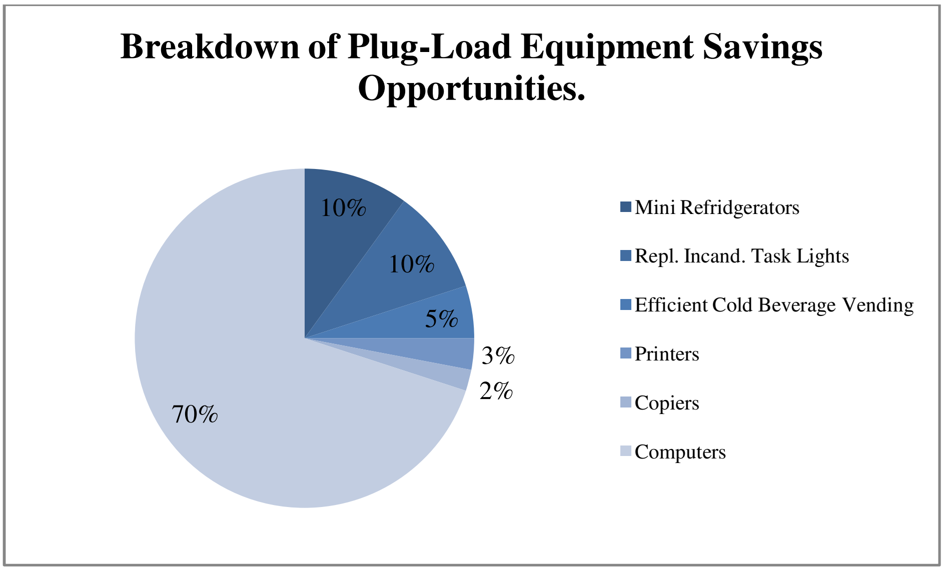


Figure 2: Breakdown of Plug-Load equipment savings opportunities. (Sabo, Andrews, Lee, & Bakalars, 2007)

The amount of electricity consumed by plug load equipments is determined by the energy efficiency of the equipments and how they are operated by building occupants. Since most of them are ENERGY STAR® qualified office equipments, which have high enough energy efficiency, the more effort should put into managing and controlling their usage pattern.

2.2 Retrofitting Lighting system

As mentioned before, there were lighting retrofitting projects (including replacing T12 lamps to T8 lamps) that have been done for both of the buildings in 2002 and 2006. (Eco TREK) Replacing all T8 lamps with T5 lamps could be one possible measure to further increase the lighting energy efficiency. However, there are some barriers that prevent this measure from being a good option in the near future. These barriers include:

- The life time for a project of updating T12 lamps to T8 lamps usually is 13 years (PA consulting Inc., 2009), part of energy and cost savings from the former retrofitting projects will not be realized, and a huge amount of further investment will be needed for purchasing new T5 lamps (3 to 4 times more than T8 lamps) and updating existing lights fixtures by implementing this measure in the very near future.

- Although T5 lamps perform better at 35°C (95°F), the differences in performance of these two lamps are almost negligible at 25°C (77°F), which more close to room temperature. (Lighting Research Center, 2002)
- Unlike T8 lamps that have been widely tested and tried in many applications for a relative long time, the T5 lamps are still under research and development, and lack of the testing and application data. (Lighting Solutions, 2009)

2.3 Behavior Changes

Compared to technical energy conservation measures, as the result of the increasing population and demand of energy per capita, the behavior change is sometime more important and is considered as the cornerstone of a sustainable future. (McKenzie-Mohr, 2000)

Unfortunately, most behavior changing programs featuring only the information campaigns have failed to prove their effectiveness and impacts on what people do (behaviors). Community-based social marketing approach, founded by Dr. Doug McKenzie-Mohr a decade ago, has emerged as an effective alternative to information-intensive campaigns for fostering sustainable behavior. There are five steps to implement this approach, which include:

- selecting behaviors to be promoted,
- identifying barriers to the behaviors,
- developing strategies to overcome the barriers,
- conducting a pilot,
- and broad scale implementation. (McKenzie-Mohr, 2000)

In this study, only the first step has been done regarding different behavior changing measures due to the limitation of time and information. Further studies and researches are still needed to complete the all five steps for this approach to achieve a more desirable improvement.

3.0 BACKGROUND

General Administration and Services Building (GSAB) and Brock Hall were selected as test sites for this project. Information on the buildings is from the university documentation and reports wherever possible. Additional data were obtained through site visits, discussions with the campus sustainability Office and building management personnel.

3.1 Building (Test Sites) Information

3.1.1 General Administration and Services Building

General Administration and Services Building is located at 2075 Wesbrook Mall. It was built in 1969 with four floors including the basement. The whole GSAB building functions as an office building while serving the following departments: Accounts Payable, Finance, Health, Safety and Environment, Human Resources (HR), IT, Parking and Access Control Services, Supply Management, and TREK office. The total floor area is about 5,829 m^2 (62,743ft^2).

As a result of EcoTREK retrofitting project in 2002, fluorescent fixtures account for more than 90% of the interior lighting of GSAB, and a majority of the fixtures have T8 lamps with electronic ballasts. The lighting system is controlled manually; the occupants in both the private/open office environments have been asked to turn off the lights when they are leaving. Some of the lights of the open offices are controlled by more than one switch, which allow the occupants to turn on/off the lights according to different daylight level or needs, but not every occupant knows well where these switches are located, and how the lights have been controlled by different switches.

Approximately half the occupants in GSAB shut down their desktops after hours. The other half just log the desktops off and leave them on either because of needs of overnight back-ups (Supply Management department and Parking and Access Control Services department) or their personal decisions. The overnight back-ups schedule can't change because of its old network system. All other office plug loads such as printers, copiers, coffee makers, water coolers are on 24/7, some of them go into energy save mode when they are not being used if there are build-in programs.

3.1.2 Brock Hall Building

Another site is Brock Hall which is located in 1874 East Mall. It is comprised of the following three parts, which no specific sub meter is available for each of them at present. The three parts are:

- Brock Hall East with an area of 5,570 m^2(built in 1993)
- Brock Hall West with an area of 2,900 m^2 (built in 1940)
- Brock Hall Annex with an area of 2,129m^2 (built in 1956)

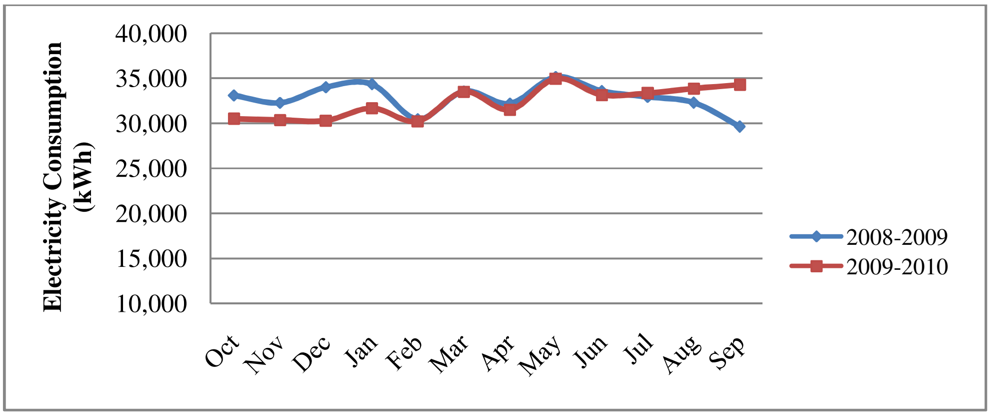
Faculty and staff hours are from 8:30 Am to 4:30 PM for both buildings. Very few staff come earlier and remains late while the facility is largely unoccupied during the nighttime and weekend hours. More student involvement is undergoing in Brock Hall building than GSAB, there are 10-15% of desktops are for students uses, and some student activities occurs in the evenings and weekends in Brock Hall. Since only one day per week has been needed for IT overnights backups and updates, it is more likely that more people in Brock Hall shut down their computer after hours than in GSAB. Both buildings are open all year around except 3 to 5-day break during Christmas.

3.2 BASELINE DATA AND ANALYSIS

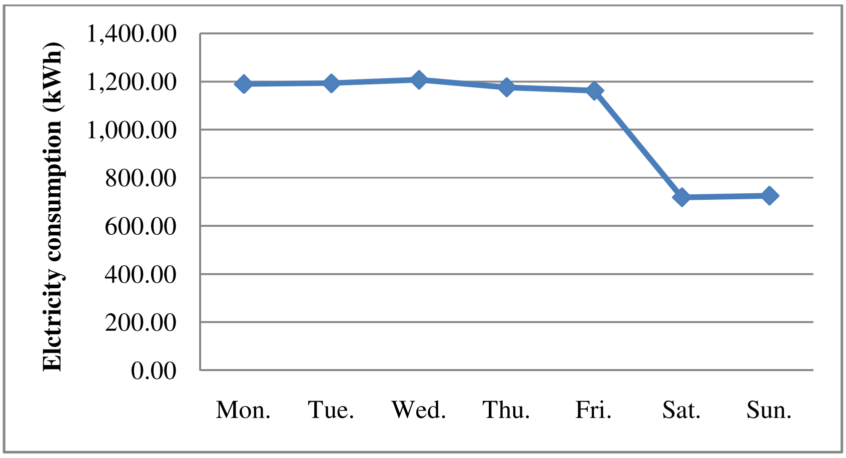
The data was obtained through either the Pulse on-line energy monitoring system or ION meter for the baseline data analysis. Since North Parkade also shares the same electrical meter with other parts of Brock Hall building, and has a very constant base load of 567,490 kWh/year, therefore, the electricity consumption of North Parkade has been deducted wherever is possible.

Only electricity data of year 2008-2009 and year 2009-2010 has been studied for the purpose of this project. (See APPENDIX B for detailed electricity data.)

3.2.1 Electricity Consumption Patterns of GSAB



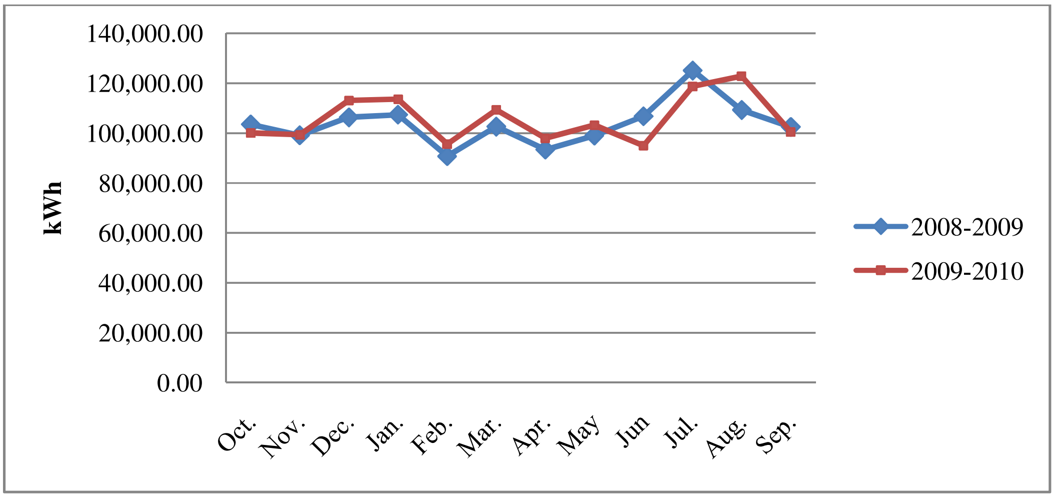
(a) Monthly Pattern.



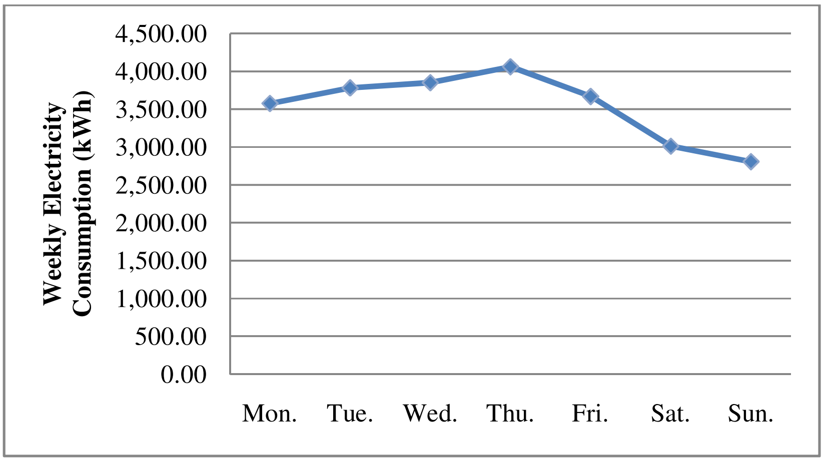
(b)Weekly Pattern (Oct 28, 1010-Oct 24, 2010)

Figure 3: GSAB electricity consumption patterns. (The Pulse System)

3.2.2 Brock Hall Electricity Consumption Patterns



(a) Monthly Pattern.



(b) Weekly Pattern. (Oct 28, 1010-Oct 24, 2010)

Figure 4: The electricity consumption patterns of Brock Hall. (The Pulse System)

3.3 Breakdown of Electricity consumption

There is no actual electrical energy consumption breakdown data available for two studied sites. The possible electricity breakdown data is obtained either through the information of UBC continuous optimization program of other two pilot buildings, or other studies that have been done before. The following table summarizes the typical breakdown data for plug load equipments and lighting system of buildings.

Description	Plug-load/Office Equipments	Lighting	Sources
Neville Scarfe building	11%	46%	(SES Consulting, 2010)
Buchanan Tower	32%	28%	(SES Consulting, 2010)
Typical office building	16%	35%	(BC Hydro, Questions & Anwers, 2005)
Typical office building	16%	30%	(University of California, 2007)
Typical office building	12%	33%	(NRC), 2000)
Typical office building		40%	(Kreith, 1999)
Typical office building	7% (only for office equipment)	30-50%	(Krarti, 2000)
Typical office building	>20%	32%	(Moorefield, Frazer, & Bendt, 2008)

Table 1: The plug-load and lighting electrical energy consumption breakdown for typical commercial office buildings.

These studies show that, on average, lighting requires about 35% total electrical energy consumption, and plug-load equipments account for more or less 16% of the total electricity use.

The following table shows the estimated electric energy consumption for plug-loads and lightings systems for two buildings of Y08-09 and Y09-10.

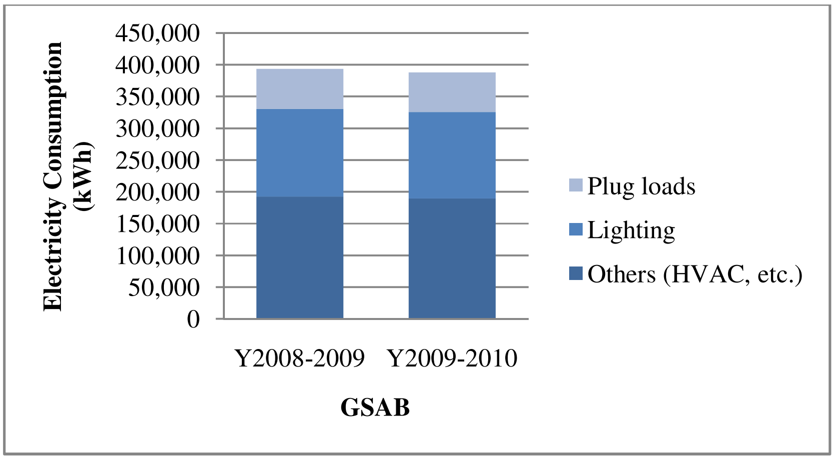


Figure 5: The breakdown of electricity consumption for Plug loads and lighting in GSAB.

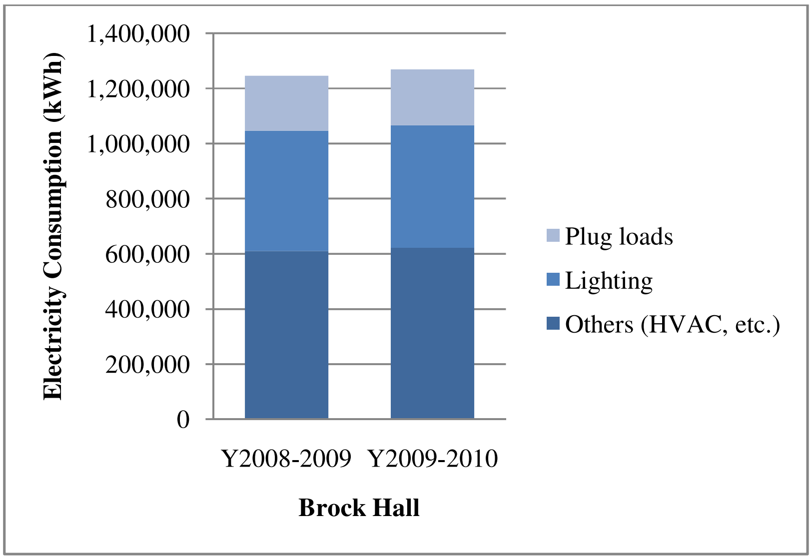


Figure 6: breakdown of electricity consumption for Plug loads and lighting in Brock Hall.

4.0 POTENTIAL ENERGY-SAVING MEASURES & SAVING ESTIMATION

The saving estimation data is calculated under the following assumptions: (1) there is no change of the electricity cost during the expected life time of each measure; (2) interest rate is 6%; (3) replacement period of office desktops is three years; (4) the life time of behavior change measure is one year; (5) each measure is stand-alone action.

4.1 Plug Load

There are three potential measures have been considered in this study to reduce the plug loads in buildings, which are:

- installing 3rd-party desktop power management software;
- using Smart Power Strips instead of regular power bars;
- improving employees' plug-load awareness and practices, therefore, cut down plug loads electric energy consumption.

4.1.1 Installing Third-party desktop power management software

Numbers of software have been developed to solve the problems with implementing the energy management policies through networked desktops. Although different software has different features, most of them could achieve common features whenever they are needed, which include:

- putting computers/monitors into low energy mode or sleep;
- shutting down computers completely:
- group-specific power-management settings;
- wake-on-LAN capability;
- control over internet(as well as LAN).

Although UBC control IT group just started a long-term virtualization plan to implement 1000 virtual desktops every year (Zaremba, 2010), in the interim installing third-party desktop energy management software on the desktops still with physical machines at the network level is one of the potential energy saving measures to reduce the electricity consumptions.

The estimated energy saving information by this measure has been given in the table below under the assumptions that the cost of software per computer is $14 after funding by BC Hydro's Product Incentive program, and the energy saving per computer is 320kWh/year. (BC Hydro, Two steps to big energy savings on desktop computers, 2009)

Using 3rd party desktop energy management software		
	GSAB	Brock Hall
Type of energy saved	Electricity	Electricity
Expected life time (years)*	2	2
# of computers	150	250
Annual energy savings(kWh)	48,000	80,000
Annual Energy savings($)	$2059.00	$3432.00
Lifetime energy savings (kWh)	96,000	160,000
Estimated capital costs *($)	$2,100	$3,500
Operation & Maintenance costs	$150	$250
Payback time (years)	1.0	1.0
Net Present Value	$1400.31	$2526.52
Cost effectiveness of savings($/kWh)	0.015	0.016

Table 2: The estimated energy savings by using 3rd party power management software.

(* (Mazzi, 2010), (BC Hydro, Two steps to big energy savings on desktop computers, 2009) and (BC Hydro, Power Smart Product Incentive Program:All Eligible Technologies, 2010))

4.1.2 Using Smart power strips

Unlike traditional power bars, "smart" power strips have the extra features that switch power on/off to unused equipments on the strip by equipped with a variety of monitors, timers and sensors.

Assuming one current-sensing Smart Power Strip is used for one workstation in order to achieve the goal of electrical energy reduction, according BC Hydro's estimation, there will be 100 kWh/computer/year savings after using Smart Power Strips, (BC Hydro, Two steps to big energy savings on desktop computers, 2009), the costs of each smart power strip is $10-$15 more than the price of regular power bars, the potential energy savings data shows as follows (Noted: no electricity savings by other plug loads such as monitors, printers, copiers etc have been considered for the estimation below):

Using Smart Power Strips		
	GSAB	Brock Hall
Type of energy saved	Electricity	Electricity
Expected life time (years)*	4	4
# of computers	150	250
Annual energy savings(kWh)	15,000	25,000
Annual Energy savings($)	$644	$1,073
Lifetime energy savings (kWh)	60,000	100,000
Estimated capital costs **($)	$4,200-6,450	$7,000-10,750
Operation & Maintenance costs	0	0
Payback time (years)	6.5-10	6.5-10
Average Net Present Value	-$2770	-$5284
Cost effectiveness of savings($/kWh)	/	/

Table 3: Estimated energy savings by Smart Power Strips.

(* (Mazzi, 2010), ** (BC Hydro, Power Smart Product Incentive Program:All Eligible Technologies, 2010) (BC Hydro, Two steps to big energy savings on desktop computers, 2009))

The estimated data above showed that the payback time is expected to be more than the lifetime of this measure, and the average Net Present Value is negative, then this measure seems not economically viable.

4.1.3 Behaviors changes

The possible behaviors change could be improving the employees' operating practices to shut down or even unplug more computers, LCD monitors and other plug load equipments after-hours.

Assuming that 25% plug-loads energy reduction could be achieved by improving occupants' operation practices, and the $500 and $850 could be needed for incentive program for GSAB and Brock Hall respectively, the estimated saving data of above potential measure shows as follows:

Improving operation practices		
	GSAB	Brock Hall
Type of energy saved	Electricity	Electricity
Expected life time (years)	1	1
# of computers	150	250
Annual energy savings(kWh)	15,622	50,302
Annual Energy savings($)	$670	$2,158
Lifetime energy savings (kWh)	15,622	50,302
Estimated initial capital costs ($)	$500	$850
Operation & Maintenance costs	0	0
Payback time (years)	0.7	0.4
Net Present Value	$132.25	$1,202.45
Cost effectiveness of savings($/kWh)	0.0085	0.024

Table 4: Estimated savings by improving operation practices.

4.2 Lighting System

4.2.1 Utilizing Lighting Control System

There are many lighting control systems available in the market that automatically controls the lights when the area is not occupied or other light sources are available, which mainly controlled by following technologies: (1) occupancy sensors, (2) personal dimming control, and (3) daylight control.

Lighting control systems that involve wiring are very expensive to install for existing buildings, therefore some wireless lighting controls technologies seem more cost effective for building retrofitting projects. Moreover, wireless lighting control system works well with either or all three controlled technologies that mentioned above.

The following table shows the estimated energy saving by installing wireless lighting control system by assuming that wireless ballast costs about $75 each (Teasdale, Rubinstein, Watson, & Purdy, Adapting Wireless Technology to Lighting Control and Environmental Sensing, 2005), and a combined 45% energy saving(all three technologies are working together) could be achieved. (Galasiu, Newsham, Suvagau, & Sander, 2007)

Using wireless Lighting Controls		
	GSAB	Brock Hall
Type of energy saved	Electricity	Electricity
Average Expected life time (years)*	10.5	10.5
Expected Lighting energy reduction	45%	45%
Annual energy savings(kWh)	61,512	198,062
Annual Energy savings($)	$2,639	$8,497
Lifetime energy savings (kWh)	645,876	2,079,651
Estimated capital costs ($)	$125,140	$227,546
Operation & Maintenance costs	0	0
Payback time (years)	47.4	26.8
Net Present Value	$-105,012.54	$ 56,311.39
Cost effectiveness of savings($/kWh)	/	/

Table 5: Estimated energy saving by using wireless lighting controls. (* (PA consulting Inc., 2009))

Apparently, both the estimated payback time are longer than this project's life time, therefore, this measure is unlikely to be a practical measure for both buildings unless the technologies with lower capital costs could be available.

5.0 BUILDING TESTS AND FURTHER DATA COLLECTION

5.1 Tests

A series of tests have been done intended to quantify the actual impacts of some of the conservation measures on plug loads in previous sections.

5.1.1 Smart Power Strips Test

Although the previous calculation for this measure did not show appealing results, field measurements were still conducted in one workstation at GSAB and one workstation at Brock Hall to qualify its actual impacts. A typical power bar and a smart power strip were used to see the impact of this measure on electricity consumption. This test included two parts, the first part is to measure the current energy consumption of a workstation without using smart power strip, and the second part is to measure the energy consumption of the same workstation using the smart power strip. The total time of this test was two weeks with one week for each part of the test. The results were recorded at 24-hour interval for further calculation.

The Smart Power Strip used in this test was CCI (Coleman Cable, Inc) 2250 Joules Smart Power Strip with surge protector and six outlets. Each costs $34.99. $7 of rebate for each Smart Power Strip could be obtained from BC Hydro's Power Smart Product Incentive Program. The manufacturer claims that the product will automatically turns off idle devices and the expected energy savings will up to $36/year.

This current-sensing power bar has three outlets controlled by one control outlet. There are two uncontrolled outlets (always-on outlets) as well. Equipments plugged into the controlled outlets are turned on and off based on current changes of the control outlet. (Refer to APPENDIX C for a detailed picture)

If you plug your computer into control outlet, as soon as your computer goes to sleep or is shut down, all other devices plugged into the controlled outlets such as monitors, task lights, and printers etc are shut down due to the current changes of the control outlet.

As mentioned before, the devices that plug in the controlled outlets are controlled by the change of current of the control outlet, which only happens when either the hard drive is shut down or it goes to sleep or energy save mode by the Windows' built-in power management application. Therefore the performance of Smart Power Strip during working hours completely relies on the Windows built-in power management settings.

Unexpectedly, both the test workstations' settings haven't been adjusted before, in order to carry on this test, the built-in power management settings of the workstation in Brock

Hall has been adjusted for whole two-week test period, and the other one in GSAB was adjusted in the beginning of the 2nd week when Smart power Strip was employed. (Refer to the table below)

The power settings of the tested desktops in GSAB and Brock Hall are as follows:

	GSAB (2nd week)	Brock Hall
Turn off the monitor after	15 minutes of inactivity	
Turn off the hard disk after	Never	30 minutes of inactivity
System stand-by after	30 minutes of inactivity	

Table 6: The power settings of built-in Windows power management for two tested desktops.

Although the test results in GSAB show 0.2kWh of reduction per work day in 2nd week compared to the data of 1st week, the results in Brock Hall show that there were no changes of electricity consumption before and after using the Smart Power Strip. (See APPENDIX D) Therefore, the power reduction was more likely to be attributed to the built-in power management settings, and optimizing the desktop's built-in power management settings turns out to be another energy conservation measure that is even better than using Smart Power Strip due to its low capital cost.

The potential annual energy savings by adjusting the built-in power management settings are as follows:

Activating the built-in power management settings		
	GSAB	Brock Hall
Type of energy saved	Electricity	Electricity
Expected life time (years)	3	3
# of computers	113	250
Annual energy savings(kWh)	5,850	13,000
Annual Energy savings($)	$250.97	$557.70
Lifetime energy savings (kWh)	17,550	39,000
Estimated capital costs ($)	$563	$1,250
Operation & Maintenance costs	0	0
Payback time (years)	2.2	2.2
Net Present Value	$1,875	$241
Cost effectiveness of savings($/kWh)	0.107	0.006

Table 7: The potential electricity savings by optimizing the built-in power management settings.

5.1.2 Desktop Power management software Test

The Faronics Power Save has been chosen to use as an example to test out the 3rd party desktop power management software, as it is recommended by BC Hydro and part of the desktops in UBC are already using other Faronics products and familiar with its environments. The cost of this software is $7.20 per license, after deducting of $5.4 (75% license costs) from BC Hydro's Power Smart Product Incentive Program, the actual cost of each license is $1.80. $10/year for each desktop is assumed to be the O&S costs for this measure.

With the help from Robert Padwick, the Desktop Services Manager of UBC, ten Records and Registration' desktops in Brock Hall were managed to be installed with the Faronics Power Save. According to the real energy consumption report of the software, 1.26 kWh of electricity has been saved per desktop after one-week testing period (from Nov 23, 2010 to Dec 1, 2010). Therefore, the potential energy saving data is calculated as follows:

Using 3rd party desktop energy management software		
	GSAB	Brock Hall
Type of energy saved	Electricity	Electricity
Expected life time (years)*	2	2
# of computers	150	250
Annual energy savings(kWh)	9,828	16,380
Annual Energy savings($)	$421.62	$702.70
Lifetime energy savings (kWh)	19,656	32,760
Estimated capital costs ($)	$270	$450
Operation & Maintenance costs($)	$150	$250
Payback time (years)	0.6	0.6
Net Present Value ($)	$227.99	$379.98
Cost effectiveness of savings($/kWh)	0.0116	0.0116

Table 8: The potential energy savings by using 3rd party desktop energy management software.(* (Mazzi, 2010)

5.2 Further Lighting Data Collection

Since there are no very promising technical measures for GSAB to lower lighting electricity consumption currently, more observation and monitoring are needed in order to come up with behavior solutions. Since GSAB is locked after 4:30 PM every weekday, and it was difficult to arrange after-hours access with such a short time period, in order to get a general ideal about the operating level of lighting after-hours, multiple exterior site inspections were chosen to gather more insight information to assess levels of lighting operation in GSAB.

After two-week site inspections during weekdays after-hours (5:30 PM-5:45 PM) from outside the GSAB building, and analysis of pictures taken of four sides of the building, the findings showed that about 30% lights in average were left on(See Table 9) after-hours.

Date		North Side	West Side	South Side	East Side
15-Nov-10	Mon.	50%	28%	27%	60%
16-Nov-10	Tue.	43%	24%	7%	64%
17-Nov-10	Wed.	36%	28%	7%	68%
18-Nov-10	Thu.	36%	17%	7%	44%
19-Nov-10	Fri.	14%	28%	20%	44%
22-Nov-10	Mon.	50%	31%	27%	52%
23-Nov-10	Tue.	32%	22%	20%	68%
24-Nov-10	Wed.	36%	24%	20%	84%
25-Nov-10	Thu.	43%	14%	17%	52%
26-Nov-10	Fri.	18%	9%	7%	36%

Table 9: The results of percentage of lights on that are supposed to be off after hour in GSAB by multiple site inspection.

The results suggested that reducing the numbers of lights on after hours will also be a good measure to reduce the electricity consumptions. Assuming the lights that are left on after hours can be reduced to 15% (Given that there might be some lights left on because of the need of staff working late), and the electricity consumptions could be reduced by 10 % due to this measure. Assuming that the cost of an incentive program is $500, the potential energy saving data is as follows:

Turn off the lights after hours in GSAB	
	GSAB
Type of energy saved	Electricity
Expected life time (years)	1
Annual energy savings(kWh)	13,669.4
Annual Energy savings($)	$586.42
Lifetime energy savings (kWh)	13,669.4
Estimated capital costs ($)	$500
Operation & Maintenance costs($)	0
Payback time (years)	0.9
Net Present Value	$53.22
Cost effectiveness of savings($/kWh)	0.004

Table 10: The potential electrical energy savings by turning of lights after hours.

6.0 CONCLUSION AND RECOMMONDATIONS

This study preliminarily identified and proposed some no-cost/low cost energy (electricity) conservation measures regarding plug load and lighting for two office buildings of UBC. The findings were summarized in the following Table (shaded areas are the valid measures proved either by literature reviews or building tests):

	GSAB			Brock Hall		
	Annual savings (kWh)	Payback period (year)	Cost effectiveness of savings ($/kWh)	Annual savings (kWh)	Payback period (year)	Cost effectiveness of savings ($/kWh)
Based on literature reviews						
Using 3rd party desktop energy management software	48,000	1	0.015	80,000	1	0.016
Using Smart Power Strips	not practical					
Improving operation practices	15,622	0.7	0.0085	50,302	0.4	0.024
Using wireless Lighting Controls	not practical					
Based on test results or multiple site inspections						
Using Smart Power Strips	no electricity saving realized					
Activating the built-in power management settings	5,850	2.2	0.107	13,000	2.2	0.006
Using 3rd party desktop energy management software	9,828	0.6	0.0116	16,380	0.6	0.0116
Turning off the lights after hours	13,669	0.9	0.004	n/a	n/a	n/a
Total annual energy Savings (kWh)	**44,969**	**1.1**	**0.033**	**79,682**	**1.1**	**0.014**

Table 11: Summary of the results upon every proposed electrical energy saving measure regarding plug load and lighting.

Overall, using 3rd party desktop energy management software was approved to be the best measure through real site testing regarding plug load, although the real test results showed a lower energy savings and shorter payback time than the estimation data based on the literature reviews.

The total energy (electricity) savings for all valid measures are expected to be 124,651 kWh (it included 44,969 kWh for GSAB and 79,682kWh for Brock Hall), and a total of

$5,347 in annual cost savings (it included $ 1,929 for GSAB and $3,418 for Brock Hall). An average simple payback period for these measures is approximately 1.1 years, and the average cost effectiveness is about $0.033/kWh for GSAB and $0.014/kWh for Brock Hall.

This study is just the first step toward systematic effort for implementing above energy conservation measures. The next step may include:

-Continuous monitoring and metering energy end uses in as more detailed scale as possible, since the success of any energy conservation measure, particularly the behavior changing measures will require careful consideration of the uniqueness of each department/building characteristics. Considering a huge amount of money might be needed for detailed building submetering (presumably if an office building were suitably wired, meters could be applied to lighting circuit and plug load separately, a ballpark figure of $10-20,000 is needed to submeter this building floor by floor (Zaremba, 2010)), the campus-wide application should start with one or two pilot sites(departments or buildings) to obtain enough information and feedback, then to evaluate and improve, if possible, its effectiveness.

-Based on different characteristics of different building components, a team of faculty, staff, students, building maintenance staff, or administration could be built in building level. These teams can help plan and conduct specific activities like student/staff lighting/plug-loads conservation patrols, and also serve as the important support for any of the future energy audits and behavior changing programs. This could also help reduce the problems of self-reported data and lack of behavior information.

-Additional research and study are needed. A review of most important barriers to adopting the existing behavior changing program is essential to understand the gaps and design any future behavior changing programs. On the other hand, follow-up surveys are needed to evaluate the efficacy after implementing any energy conservation measure.

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APPENDIX A: Commercial Sector Growing End Uses and Actual and Predicted Energy Consumption 2007-2030.

Key Indicators and Consumption (Quadrillion Btu per Year)	Reference Case							Annual Growth 2007-2030 (percent)
Year	2006	2007	2010	2015	2020	2025	2030	
Office Equipment (PC)	0.68	0.77	0.8	0.85	0.91	0.98	1.03	1.30%
Office Equipment (non-PC)	0.61	0.67	0.82	1	1.18	1.26	1.32	3%
Ventilation	1.51	1.57	1.68	1.85	2.01	2.1	2.17	1.40%
Space Heating	2.01	2.16	2.2	2.23	2.27	2.26	2.23	0.10%
Space Cooling	1.73	1.8	1.77	1.82	1.89	1.95	2.03	0.50%
Water Heating	0.77	0.77	0.76	0.8	0.83	0.86	0.87	0.60%
Cooking	0.24	0.24	0.25	0.26	0.27	0.28	0.29	0.80%
Lighting	3.41	3.41	3.36	3.44	3.58	3.64	3.71	0.40%
Other Uses*	5.59	5.82	6.11	6.66	7.33	7.96	8.71	1.80%

Table 12: Commercial Sector Growing End Uses and Actual and Predicted Energy Consumption 2007-2030. (Energy Information Administration, 2009) (* includes miscellaneous uses, such as service station equipment, automated teller machines, telecommunications equipment, medical equipment, pumps, emergency generators, combined heat and power in commercial buildings, manufacturing performed in commercial buildings, and cooking (distillate), plus residual fuel oil, liquefied petroleum gases, coal, motor gasoline, and kerosene.)

APPENDIX B: Electricity Data

Building Name: GSAB

Total Areas: **5829 Sq. Meters**

Year: 09-10

Month	# days in Billing Period	Electric usage kWh	Electric Demand kW	Electric unit Cost $/kWh	Load Factor	Electricity Cost
Oct.	31	30,488.00	75.22	0.0429	54%	$1,307.94
Nov.	30	30,361.16	76.93	0.0429	55%	$1,302.49
Dec.	31	30,289.34	78.40	0.0429	52%	$1,299.41
Jan.	30	31,678.87	81.70	0.0429	54%	$1,359.02
Feb.	28	30,231.38	82.46	0.0429	55%	$1,296.93
Mar.	31	33,524.44	84.72	0.0429	53%	$1,438.20
Apr.	30	31,497.88	82.28	0.0429	53%	$1,351.26
May	31	34,966.44	78.76	0.0429	60%	$1,500.06
Jun.	30	33,144.62	75.37	0.0429	61%	$1,421.90
Jul.	31	33,330.25	71.08	0.0429	63%	$1,429.87
Aug.	31	33,859.38	71.08	0.0429	64%	$1,452.57
Sep.	30	34,263.81	76.43	0.0429	62%	$1,469.92
Annual Totals	364	387,635.57				$16,629.57

Year: 08-09

Month	# days in Billing Period	Electric usage kWh	Electric Demand kW	Electric unit Cost $/kWh	Load Factor	Electricity Cost
Oct.	31	33,102.40	79.67	0.0429	56%	$1,420.09
Nov.	30	32,259.83	82.17	0.0429	55%	$1,383.95
Dec.	31	33,991.06	81.65	0.0429	56%	$1,458.22
Jan.	30	34,336.63	83.51	0.0429	57%	$1,473.04
Feb.	28	30,470.52	81.43	0.0429	56%	$1,307.19
Mar.	31	33,555.44	80.74	0.0429	56%	$1,439.53
Apr.	30	32,192.48	80.98	0.0429	55%	$1,381.06
May	31	35,154.78	77.76	0.0429	61%	$1,508.14
Jun.	30	33,574.41	73.28	0.0429	64%	$1,440.34
Jul.	31	32,924.47	73.08	0.0429	61%	$1,412.46
Aug.	31	32,284.03	72.05	0.0429	60%	$1,384.98
Sep.	30	29,624.94	73.07	0.0429	56%	$1,270.91
Annual Totals	364	393,470.99				$16,879.91

Table 13: Electricity Data of GSAB of Y08-09 and Y09-10.

Building Name: Brock Hall

Total Areas: 10599 Sq. Meter
Year: 09-10

Month	# days in Billing Period	Electric usage kWh	Electric Demand kW	Electric unit Cost $/kWh	Load Factor	Electricity Cost
Oct.	31	100,041.29	348.02	0.0429	39%	$4,291.77
Nov.	30	99,345.79	309.10	0.0429	45%	$4,261.93
Dec.	31	113,018.55	325.44	0.0429	47%	$4,848.50
Jan.	30	113,541.92	320.41	0.0429	49%	$4,870.95
Feb.	28	95,512.17	318.26	0.0429	45%	$4,097.47
Mar.	31	109,362.42	321.04	0.0429	46%	$4,691.65
Apr.	30	97,914.17	311.15	0.0429	44%	$4,200.52
May	31	103,222.67	355.96	0.0429	39%	$4,428.25
Jun.	30	94,934.67	384.25	0.0429	34%	$4,072.70
Jul.	31	118,715.17	374.91	0.0429	43%	$5,092.88
Aug.	31	122,827.42	377.32	0.0429	44%	$5,269.30
Sep.	30	100,441.42	385.89	0.0429	36%	$4,308.94
Annual Totals	364	1,268,877.66				$54,434.85

Year: 08-09

Month	# days in Billing Period	Electric usage kWh	Electric Demand kW	Electric unit Cost $/kWh	Load Factor	Electricity Cost
Oct.	31	103,560.87	409.77	0.0429	34%	$4,442.76
Nov.	30	99,143.32	315.34	0.0429	44%	$4,253.25
Dec.	31	106,385.36	312.23	0.0429	46%	$4,563.93
Jan.	30	107,439.20	300.38	0.0429	50%	$4,609.14
Feb.	28	90,782.17	300.79	0.0429	45%	$3,894.56
Mar.	31	102,655.42	304.17	0.0429	45%	$4,403.92
Apr.	30	93,431.98	308.85	0.0429	42%	$4,008.23
May	31	99,069.98	348.42	0.0429	38%	$4,250.10
Jun.	30	106,786.17	368.61	0.0429	40%	$4,581.13
Jul.	31	125,121.55	461.38	0.0429	36%	$5,367.71
Aug.	31	109,321.42	376.04	0.0429	39%	$4,689.89
Sep.	30	102,501.67	386.28	0.0429	37%	$4,397.32
Annual Totals	364	1,246,199.11				$53,461.94

Table 14: Electricity Data of Brock Hall of Y08-09 and Y09-10.

APPENDIX C: Picture of Smart Strip

Figure 7: Picture of CCI Smart Power Strip.

APPENDIX D: RESULTS FOR SMART STRIP TESTS

Department: HS &E
Building : GSAB
Devices included: Hard drive, Monitor (1), Mobile phone charger

Date	Time	Volt	Amp	Watt	VA	Hz	PF	kWh	Hours
BEFORE									
Nov.12,2010	11:07	114.8	0.11	4	13	59.9	0.31	0	0.07
Nov.13,2010	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Nov.14, 2010	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Nov.15,2010	16:10	115.7	1.65	112	179	59.9	0.62	Error	77.25
Nov.16,2010	16:45	115.2	1.59	121	204	59.9	0.62	2.52	101
Nov.17,2010	16:30	114.7	0.11	4	13	59.9	0.31	3.5	125
Nov.18,2010	16:30	115	1.59	111	185	59.9	0.6	4.52	149
Nov.19,2010	16:25	114.5	0.72	4	13	59.9	0.31	5.47	173
Nov.20,2010	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Nov.21,2010	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Nov.22,2010	9:00	115.4	1.62	115	185	59.9	0.62	5.82	238
AFTER									
Nov.23,2010	8:35	116.1	1.96	117	243	59.9	0.6	0.81	23.5
Nov.24,2010	4:30	114.2	1.56	111	180	59.9	0.62	2.45	55.3
Nov.25,2010	3:50	115.8	1.59	111	184	59.9	0.6	3.3	78.6
Nov.26,2010	9:00	114.3	1.7	114	196	59.9	0.6	3.42	95.83

Department: Classroom Services
Building : Brock Hall
Devices included: Hard Drive, Monitor (2), Mobile phone charger

Date	Time	Volt	Amp	Watt	VA	Hz	PF	kWh	Hours
BEFORE									
Nov.16,2010	15:06	118.2	1.65	128	194	59.9	0.65	0	0.1
Nov.17,2010	15:45	118.5	1.63	128	194	59.9	0.66	1.29	24.3
Nov.18,2010	15:45	118.4	1.64	129	196	59.9	0.65	2.47	48.3
Nov.19,2010	16:20	117.9	1.67	130	197	59.9	0.65	3.82	72.85
Nov.20,2010	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Nov.21,2010	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Nov.22,2010	14:00	117.4	1.7	128	200	59.9	0.64	5.15	142
AFTER									
Nov.22,2010	16:30	117	1.76	131	205	59.9	0.63	0.32	2.5
Nov.23,2010	15:47	117.2	1.7	131	199	59.9	0.66	1.49	25.75
Nov.24,2010	16:20	117.2	1.71	132	200	59.9	0.65	2.88	50.25
Nov.26,2010	7:48	117.9	1.73	132	202	59.9	0.65	4.33	89.75
Nov.26,2010	14:00	116.8	1.67	129	199	59.9	0.66	5.15	96