UBC Laboratory Peak Load Reduction:
Demand Response and Demand Reduction Opportunities for Laboratory Operations at The University of British Columbia

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by

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EXECUTIVE SUMMARY

The University of British Columbia is reaching the limits of its existing infrastructure for electricity supply to the Vancouver Campus. In 2013, demand above the 45 MVA was recorded for 554 hours of the year. These peak demand events exceed the campus capacity mandate of n-1 redundancy. Drawing on information gained from literature review and audits of a sample set of campus laboratories, this study identifies and quantifies a low cost peak demand reduction opportunity through scheduling or load shifting of major research equipment. The final deliverable in this study includes a UBC Laboratory Demand Response Pilot Program proposal and its estimated impact on Campus peak demand.

Chapter 1 of this report gives a comprehensive overview of the problem and brief literature review. Chapter 2 provides an overview of the approach and data sources used in the study. Chapter 3 provides an in depth analysis of UBC substation meter data giving insights into the duration and frequency of peak load events on campus. Based on a cumulative load frequency curve of 2013 substation data, it was found that the frequency of occurrence of peak load drops significantly above 46.5 MVA; only slightly above the 45 MVA threshold. Only ten days in 2013 does electrical demand exceed 46.5 MVA. It was found that the duration of electrical demand above 46.5 MVA ranges from 8:30 am to 7:00 pm. These days occur most often in September, November, and December months of the school year.

Chapter 4 gives results from the laboratory audit and interviews. Of the six buildings audited, representing 15% of all academic laboratory space on campus, only four laboratories were identified to have significant equipment loads that could be rescheduled during a peak load event on campus. The four labs identified could reduce peak load contribution by 143 kW, resulting in $2,718 of total Demand Charge cost savings over the September, November, and December billing periods. These loads were found to represent approximately 5% of each building's peak load. Extrapolating these results to all academic buildings on Campus with laboratory space results in 976 kW of electrical demand reduction and $6,198 in demand charge savings per billing period.

Finally, Chapter 5 details a proposed behavioural demand response pilot plan based on the information gained from Chapters 3 and 4. The pilot program proposes targeting three groups for study: 1) specific laboratories, 2) specific buildings, and 3) campus wide faculty and staff.

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CHAPTER 1

1.0 INTRODUCTION

1.1 MOTIVATION FOR THE STUDY

The University of British Columbia is reaching the limits of its existing infrastructure for electricity supply to the Vancouver Campus. At present, UBC's transmission infrastructure has an available capacity of 48 MVA (with n-1 redundancy) at the UNY substation and 13 MVA at the UNS Substation. Previous peak demand events have been recorded as high as 49 MVA. In 2013, demand above 49 MVA was recorded for 14 hours of the year and demand above 48 MVA occurred for 45 hours of the year. These peak demand events exceed the campus capacity mandate of n-1 redundancy for the UNY Substation, so the University is looking for opportunities to reduce peak demand use on Campus. One such opportunity could exist within the laboratories at UBC. Campus laboratories can consume as much as 50% of campus energy requirements (Sieb A., 2009). This study plans to examine laboratories in a subset of buildings on campus and determine the best methods for reducing the laboratory contribution to the peak load events on campus through strategies such as load scheduling and load shedding that have low or no cost of implementation. The final deliverable will include a UBC Laboratory Demand Response Plan, a Pilot Program proposal, and other recommendations for reducing peak electrical demand of research equipment at UBC.

1.2 RESEARCH OBJECTIVES AND REPORT STRUCTURE

Recent developments on campus have augmented the demand for electricity and caused the existing transmission lines to operate at their capacity during peak demand periods. The purpose of this study is to identify and quantify low and no cost peak electrical demand management opportunities through load shedding or load scheduling for academic research equipment used on Campus. The three general research questions assessed in this study are:

1. What opportunities exist on campus to coordinate and schedule research related plug loads?
2. What peak electrical demand reductions are possible through scheduling of major research equipment?
3. What is the best process for scheduling and monitoring the impact of research related plug loads?

The final deliverable for this study includes a UBC Laboratory Demand Response Plan and Pilot Program proposal, and recommendations for future research on reducing peak electrical demand of research equipment at UBC.

1.3 UBC Transmission Capacity and Peak Demand Forecast

Two existing UBC studies are helpful in providing background to this study. The first paper examines the issue of UBC's peak electrical demand in 2010 and studied a sub set of buildings with the highest contribution to this peak load. The report recommends UBC implement semi-automated demand strategies to reduce monthly peak demand by 5% (Rampley, 2010). A second project completed by S. Rostamirad evaluates an automated load shedding scheme for UBC, and provides relevant background information on UBC's transmission system.

Two transmission lines supply electricity to the UBC Vancouver Campus; North and South lines supply electricity to the UNY and UNS substations. The North and South transmission lines have thermal capacities of 62 and 42 MVA, respectively (Rostamirad, 2011). UBC's current contract with BC Hydro is 45 MVA for the North UNY Substation and retrofits to this infrastructure by fall 2014 will increase this capacity to 55 MVA (Henderson, 2014). The North Campus line from the UNY substation has a peak capacity of 47.6 MVA with n-1 redundancy as shown in Figure 1.

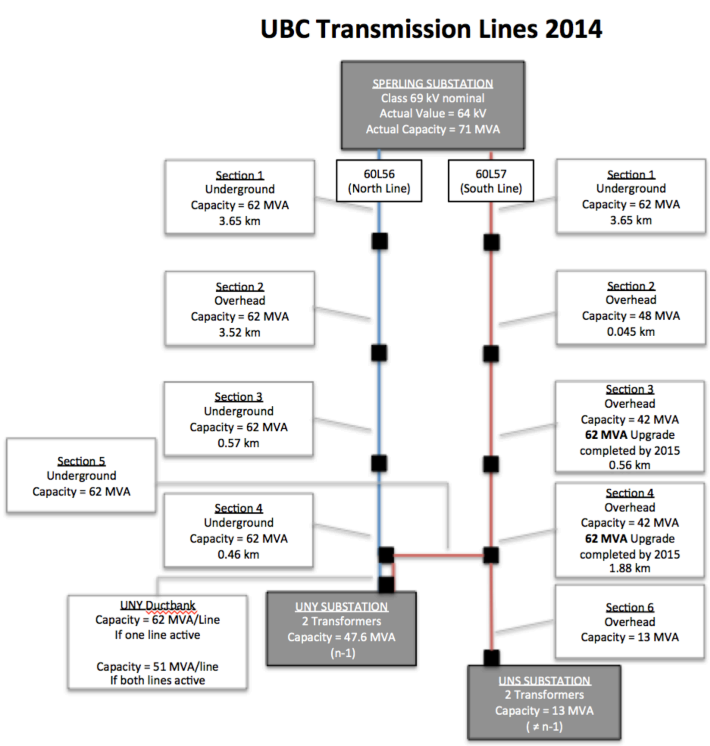

FIGURE 1 - TRANSMISSION LINES TO UBC CAMPUS (ROSTAMIRAD, 2011).

Figure 2 shows the forecasted peak demand growth for the University through to 2030 with the 45 MVA and future 55 MVA capacity benchmarks. Transmission line upgrades to 65 MVA is planned for completion by 2018 and is projected to cost anywhere between $824,951 and $2.3 Million in 2010 Dollars (Rampley, 2010). In addition to deferred costs of transmission line upgrades, reductions in peak demand will yield immediate cost savings to the University due to BC Hydro demand charges. At present, UBC is charged $6.353 per kVA of monthly peak demand (BC Hydro, 2013). For December 2013, this resulted in $311,328 in demand charges for that month alone (BC Hydro, 2013).

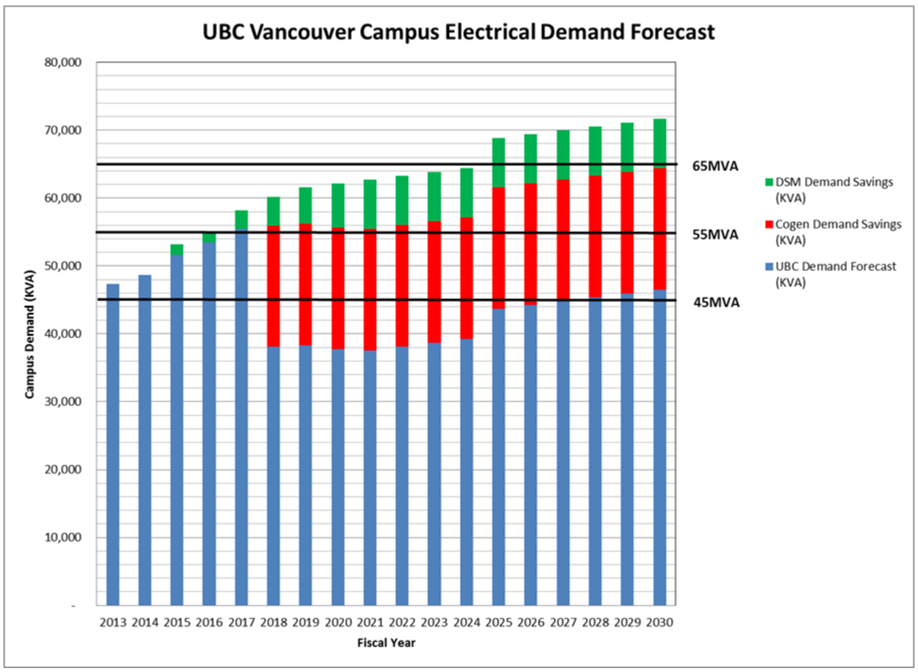

FIGURE 2 - UBC PEAK DEMAND FORECAST

1.4 DEMAND RESPONSE

In the broadest sense, demand response (DR) can be defined as changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time (Albadi et al., 2007). Demand response can include incentive payments designed to reduce electricity use at peak times and includes "*all intentional modifications to consumption patterns of electricity to end-use customers that are intended to alter the timing, level of instantaneous demand, or the total electricity consumption*." (Albadi et al., 2007).

There are three main types of demand response strategies cited in literature, they are load shedding, load shifting, and load displacement. Through load shedding, customers can reduce electricity consumption during peak demand times when prices are higher than average without changing consumption patterns during off-peak periods. This option often involves inconveniencing participants and can lead to a temporary loss of comfort (Albadi et al., 2007). An example of load shedding would be reducing office lighting levels or thermostat setback. As an alternative to load shedding, program participants can shift loads from peak times to off peak periods through load scheduling. This option does not involve loss of comfort but may be still inconvenience the participant (Albadi et al., 2007). Load displacement is a third demand response action cited by Albadi et al. that makes use of standby on-site generation (distributed generation) to offset the use of grid-supplied electricity. This option has the least impact in terms of inconveniencing the end use consumer while still reducing demand from the utility provider (Albadi et al., 2007).

One method for achieving these demand response strategies cited in literature includes behavioral change. Both load shedding and load shifting, and to some extent, load displacement can be achieved through behavioral changes from energy consumers. This option is often a large part of manual demand response programs and is the lowest cost and lowest risk demand response option. Because the UBC laboratory demand reduction program will favour low-cost or no-cost measures, behavior change by the researchers will be the focus of this study. Based on this assumption, the pilot program should incorporate strategies proposed by McKenzie-Mohr's community-based social marketing approach. These strategies include: commitment, social norms, social diffusion, prompts, communication, incentives, and convenience. A five step process is identified in the community-based social marketing approach as: 1) Selecting behaviours, 2) Identifying barriers and benefits, 3) Developing strategies, 4) Piloting, and 5) Broad scale implementation and evaluation (McKenzie-Mohr, 2011).

1.5 STUDY CHALLENGES

A preliminary search for publications specifically on demand reduction and scheduling of equipment in laboratories results in few papers. There are, however, many publications on more holistic demand response programs as well as publications on energy efficiency in laboratories. It seems there is a research gap in demand response and demand reduction initiatives in this area. This could be due to the potential challenges of reducing demand the peak demand of the equipment. Barriers such as insufficient motivation to invest in new equipment and the reliance on individuals in laboratories to use the equipment in an energy conscience manner have been cited. For research laboratories at Universities, equipment is also constantly changing, and these changes can make it difficult to standardize a demand reduction process. The majority of papers found on laboratories tend to focus on optimizing HVAC control measures, ventilation rates, and reducing fume hood exhaust, few focus on electrical plug loads.

Laboratory-type facilities use a considerable amount of energy; energy intensities have been found to be 4 to 5 times higher than ordinary (non-laboratory) buildings (Mills et al., 1996). They are also vital to the success of research at Universities. The potential for demand and energy savings in laboratories could be large, however it proves to be a challenging task.

CHAPTER 2

2.0 METHODOLOGY AND DATA SOURCES

2.1 UTILITY DATA COLLECTION

A number of campus building sub meters are available through the ION and Pulse metering system. Electrical data from the past 4 years was downloaded from the ION system for all available Campus buildings connected to the Pulse system, as well as the past 4 years of data on the UNY and UNS substations from ION. The ION data was used to determine the campus peak load events and their frequency through the use of a cumulative load frequency graph, histogram, and graphical methods.

The Pulse data was used to determine the peak load of the buildings audited. Buildings selected for this study were required to have an electrical meter that is connected to the Pulse system, and significant laboratory floor space.

2.2 LABORATORY AUDIT AND EQUIPMENT INVENTORY

UBC Risk Management Services was initially consulted for buildings that may fall within scope. Once the sample set of buildings was identified, a preliminary interview was done with the lab or facility manager to determine whether the building would still be a good candidate. The following questions were asked to the lab/building facilitator to determine the whether the building was a good candidate:

1. What type of laboratories existed in the building?
2. What type of loads existed in these laboratories and how large were they?[1]
3. Based on the Facilitator's knowledge of the researchers and laboratory operations, did they think there was an opportunity in the labs to schedule plug load use around campus peak load events?[2]

If the building had laboratories with point source plug loads greater than 7.5 kW, the laboratory was audited and researchers conducting research in the laboratory were interviewed. A preliminary walk through of the lab was done to review the laboratory equipment, their make and model number as well as rated power was documented using photos. Researchers or the lab manager was interviewed to determine

[1] It was determined early in the investigation that small, distributed loads (less than 10 HP) were not ideal candidates, as rescheduling small loads was highly disruptive to multiple researchers while having a relatively small impact on peak demand. For this reason, the study focuses on large plug loads, greater than 7.5 kW.

[2] The selection of buildings based on these questions could result in selection bias in the results. This is important to note and is addressed later in the study when results are extrapolated to a Campus-wide representation of demand savings.

the schedule of the equipment. Specifically, how often the equipment was used (diversity factor) and when the largest demand for the equipment was.

With the laboratory equipment inventory complete for the sample building set, the audit and interview information was organized and analysis completed to determine whether the laboratory would be a good candidate for a pilot program. Appendix A summarizes the main points from those interviewed.

CHAPTER 3

3.0 UBC PEAK DEMAND ANALYSIS

Campus peak demand has been recorded as high as 49 MVA. This load occurred on December 9th, 2013 at 1:30 pm and includes loads from both the UNS and UNY substations. Figure 2 shows the load frequency of the UBC Vancouver Campus from January to December 2013 and Figure 3 gives this data as a Load Duration Curve; ranking hourly demand values from highest to the lowest, irrespective of when they occur in the year. This presentation of data is helpful as it gives insight into the duration of peak load events on campus. For instance, loads above 49 MVA occurred for 14 hours of the year and there is a significant drop in demand frequency above 46 MVA in 2013, which occurs for 275 hours of the year.

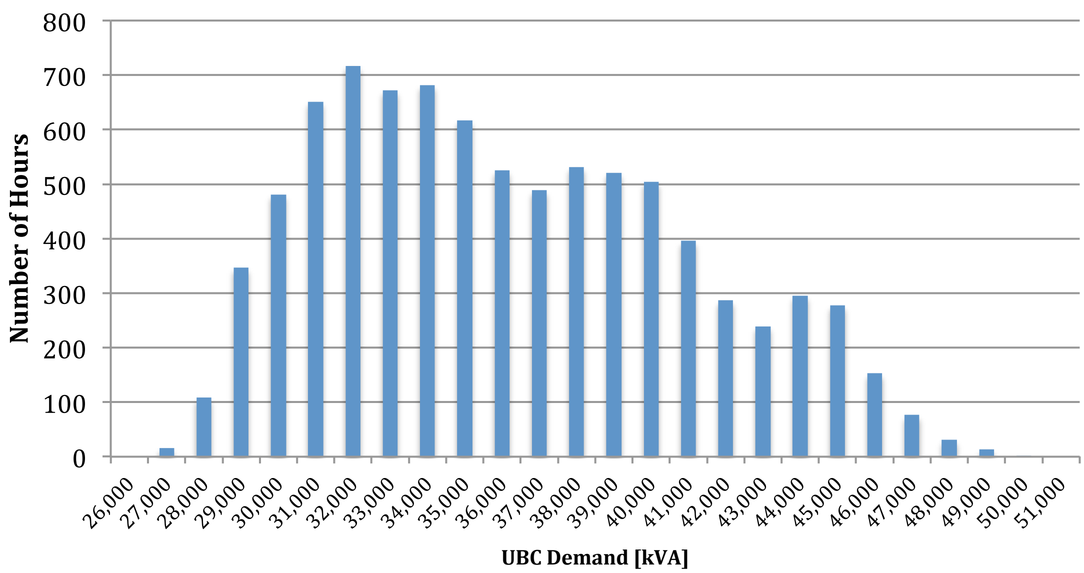

FIGURE 3 - CAMPUS DEMAND LOAD FREQUENCY CURVE, 2013

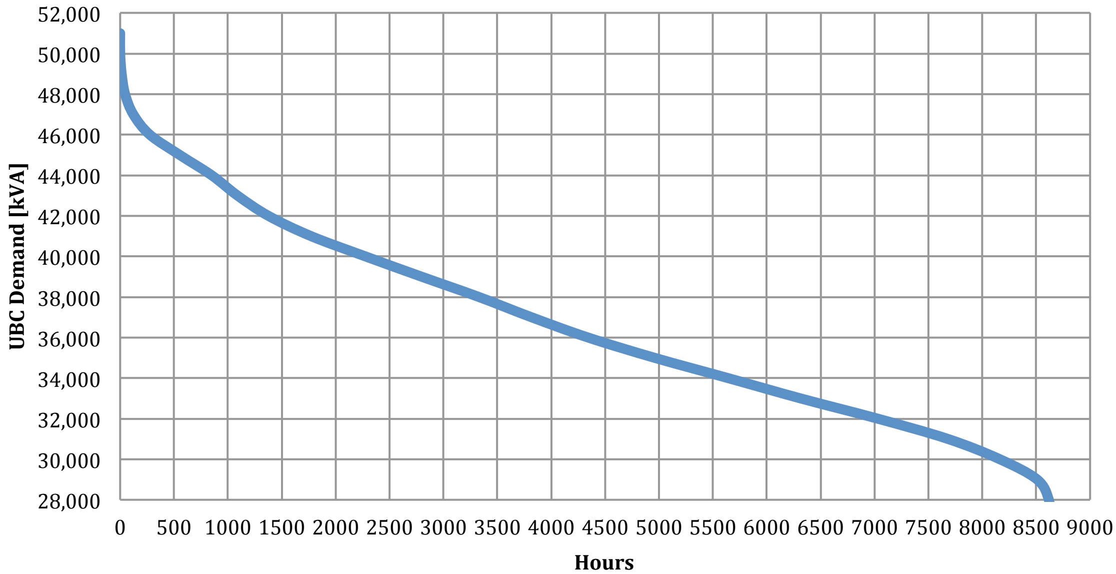

FIGURE 4 – CAMPUS CUMULATIVE LOAD DURATION CURVE, 2013

Figure 5 and 6 give the hourly peak demand for every day where demand on campus exceeds 46.5 MVA in in 2013. This presentation of data gives insight into the frequency of peak load above 46.5 MVA in terms of full days and shows how often a demand response program would need to be implemented in order to be effective. For instance, campus electrical demand exceeds 46.5 MVA, representing $15,883 in demand charges per billing period, from 8:30 am to 7:00 pm for ten days in 2013. It is worth note that the top ten peak demand days in 2013 occur in September, November, and December. This is illustrated more clearly in Figure 7 where the top ten demand days are seen to be crossing the orange line at 46.5 MVA. Figure 8 shows the maximum campus demand for each day of the year for 2011, 2012, and 2013 and shows the infrastructure limit of 45 MVA as a reference.

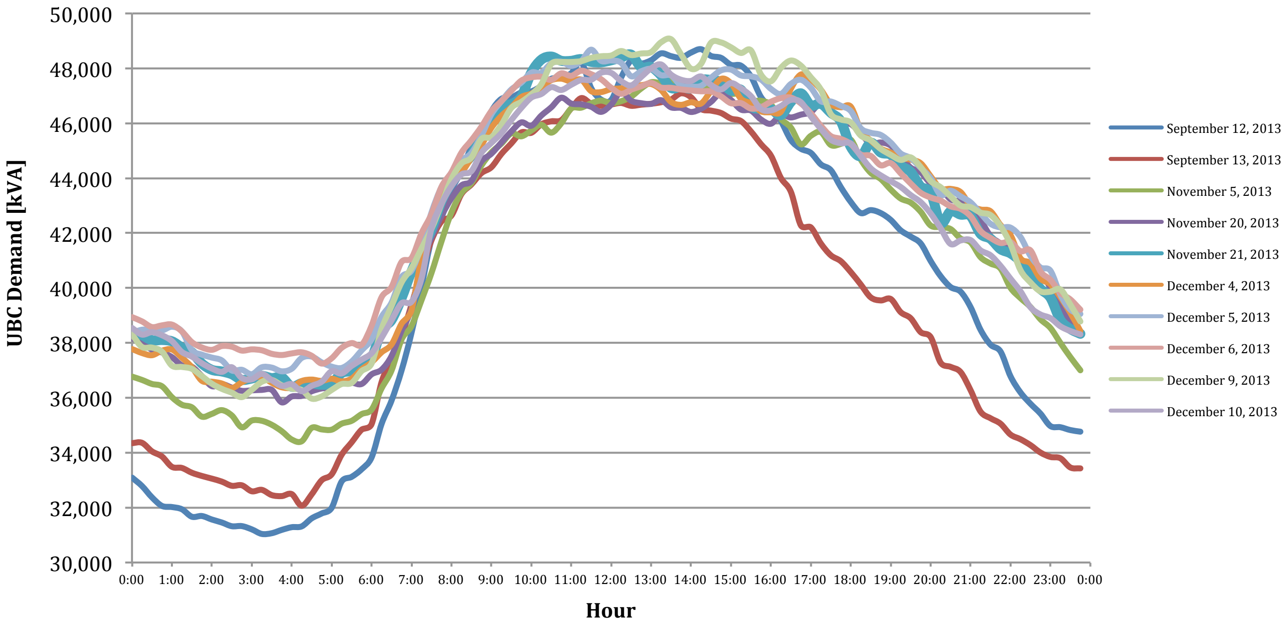

FIGURE 5 – TOP TEN UBC PEAK DEMAND DAYS, 2013

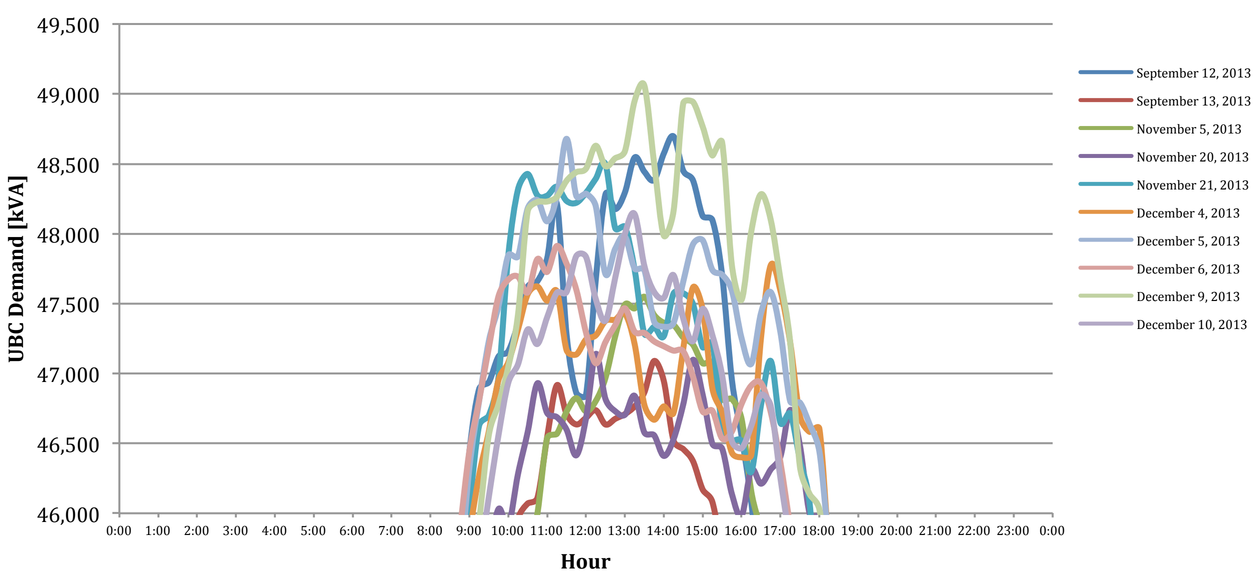

FIGURE 6 – TOP TEN ELECTRICAL DEMAND DAYS, 2013

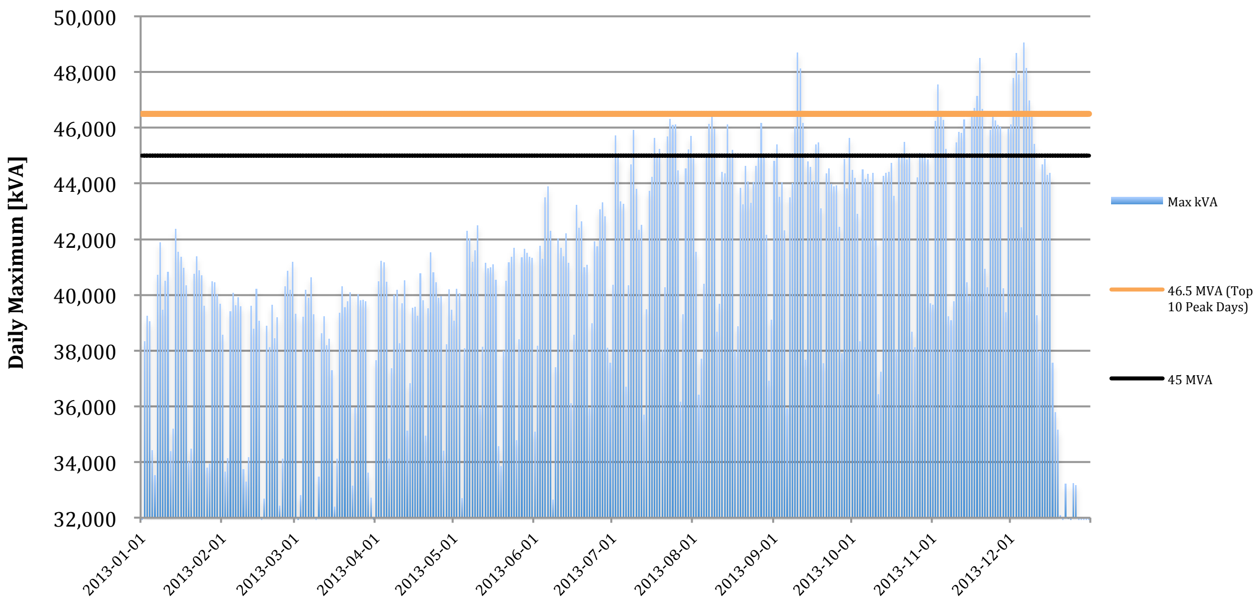

FIGURE 7 - 2013 CAMPUS MAX DAILY DEMAND

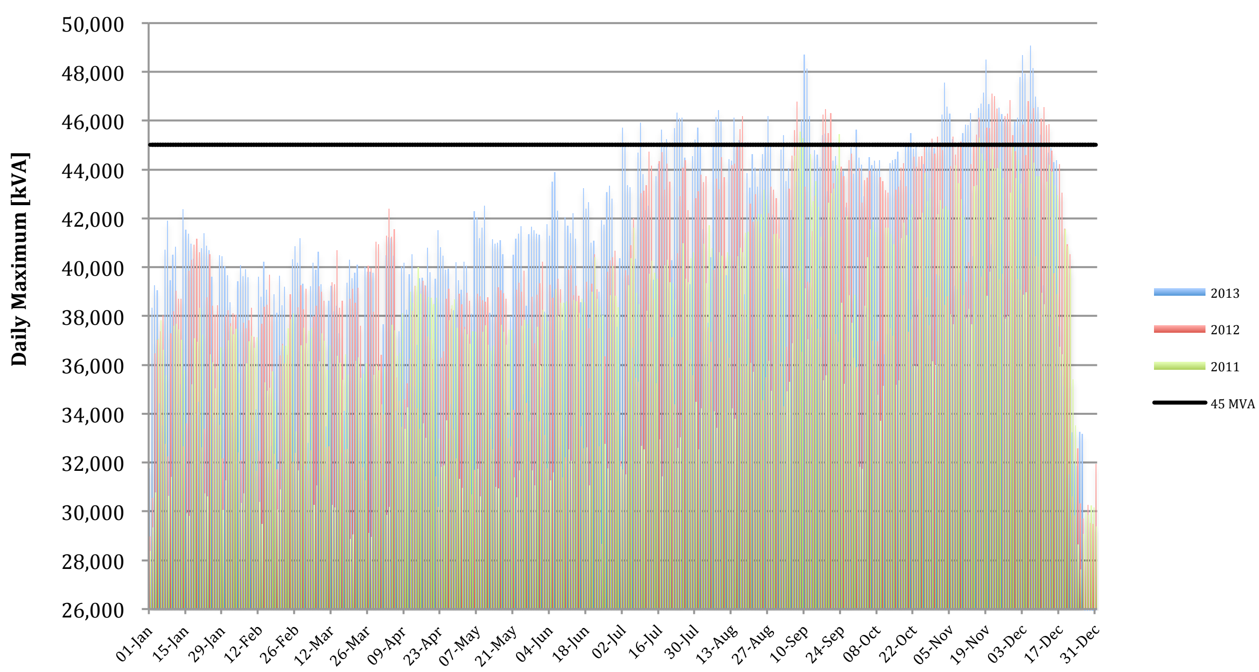

FIGURE 8 - 2011-2013 CAMPUS MAX DAILY DEMAND

CHAPTER 4

4.0 LABORATORY AUDIT AND INTERVIEW RESULTS SUMMARY

4.1 RESULTS SUMMARY

Six research-intensive campus buildings were audited for opportunities to reduce demand in laboratories. These buildings include:

- Michael Smith Laboratories
- Chemical and Biological Engineering
- Civil and Mechanical Engineering
- Forest Sciences
- Pulp and Paper
- Physics (Hennings)

Total floor area and total laboratory floor area for these buildings is given in Table 1. Together, the six buildings audited represent 15% of all campus academic building laboratory space and 10% of total academic building floor space.

TABLE 1 - BUILDING STATISTICS

Building	Building Floor Area [m^2]	Laboratory Floor Area [m^2]	% Lab Area
Physics (Hennings)	10,431	3,915	38%
CEME	8,948	2,834	32%
Chemical & Bio. Eng.	12,754	4,484	35%
Forest Sciences	23,767	7,122	30%
Pulp & Paper	3,330	1,096	33%
Michael Smith Labs	7,712	3,493	45%
Total	66,942	22,944	34%

All Academic Buildings at UBC Vancouver Campus	695,959	156,977
Percentage of UBC Space Audited	10%	15%

The majority of laboratories were found to have small, distributed electrical plug loads which are likely to have a small impact on peak demand if energy consuming research experiments were rescheduled, while being fairly disruptive to research operations. Eleven laboratory managers and lab technicians and ten graduate researchers and professors were interviewed during the laboratory audits to determine what measures could be implemented to help reduce peak load on campus. Through interviews with researchers and laboratory managers, it was discovered in the majority of cases that it is not possible to reschedule experiments. This is due to a number of reasons given by those interviewed, including:

- Time constrains on researchers: A number of lab managers, undergraduate researchers, and professors have noted that they are under time pressure to have experiments completed and rescheduling could be an issue especially with experiments that have longer setup times.
- Safety of researchers and laboratory staff. As illustrated by Figures 5 and 6, peak loads events have a long duration from 8:30 am to 7:00 pm in the evening. Scheduling evening lab times, is a possibility, however most researchers were not in favour of the idea due to safety reasons. It is most safe for researchers to work in laboratories during normal school hours when they are most alert and others present to reduce the occurrence of laboratory incidents.
- High demand of equipment use: Some equipment (the NMR instruments in the Chemistry department in particular) are under high demand from graduate and undergraduate researchers; it would be difficult to reschedule the experiments - doing so would interrupt and adversely impact student research.
- Experiments already in progress that cannot be stopped: Some experiments, especially those found in CHBE, cannot be stopped once initiated. Some experiments run for as long as 1-3 days.
- The life cycle of the research organisms: For chemical and biological research in particular, experiments must be initiated during the correct time in a sample's life cycle.

As noted in Chapter 3, campus peak load events occur frequently in November and early December when undergraduates are under time pressure to complete fall semester projects. This makes it difficult to load shift any undergraduate work which includes significant electrical loads in the machine and wood shops; representing up to 15% of CEME's and 5% of Forest Science's electrical demand.

Only four laboratories audited said they may be able to delay research or reschedule around a peak load event on campus. When in operation, these particular labs do consume a significant amount of electricity, they are: CHBE Clean Combustion Lab, Pulp and Syngas Lab, and the Forestry Wood Shop (CAWP). An opportunity for rescheduling autoclaves and ovens in Michael Smith Labs is also a possibility. Table 2 summarizes the estimated peak demand contribution from these laboratories. More detail on each lab is provided in the Sections 4.2 through 4.7.

TABLE 2 - LABORATORY PEAK DEMAND REDUCTION SUMMARY

Building	Lab	Estimated Demand Reduction [kW]	Probable Demand Reduction [kW]	Probable Demand Charge Savings/Month	Avg. Load Duration [hrs/day]	2013 Building Peak Demand [kW]	% of Peak
CHBE	Clean Combustion Lab	49	18	$117	6	668	3%
Forest Sciences	Wood Processing Shop	52	44	$279	1-4	847	5%
Pulp & Paper	Pulp & Paper Lab	99	4	$25	1	175	6%
	Syngas Lab	11	6	$37	12		
Michael Smith Labs	Building Autoclaves & Ovens	282	71	$448	1	1010	7%
Total	**All**	**493**	**143**	**$906**	**n/a**	**2700**	**5%**

Demand estimates were calculated using equipment nameplate power draw, equipment efficiency, frequency of operation, and a load factor. More detail is provided on the operations of these labs in the sections below. The equipment load available for rescheduling in these laboratories is estimated to be between 143 and 495 kW, resulting in a $906 - $3,145 reduction in demand charges each billing period. Should load shedding of this equipment occur for all peak days in September, November, and December UBC will save $2,717 - $9,406 in demand charges.

Assuming the buildings audited are a representative sample size of all academic laboratory space on campus entire campus, these results can be extrapolated to give campus wide results. Extrapolating the probable demand reduction (which includes a conservative diversity factor for equipment utilisation) using the total UBC Vancouver laboratory floor area given in Table 1, the expected demand reduction is 976 kW. This equates to $6,198 in demand charge savings per billing period and $18,594 per annum, assuming demand reductions in peak months of September, November, and December. Sections 4.2 through 4.7 go into greater detail on all buildings audited and Section 4.8 addresses specific equipment that is common to many laboratories at UBC. Summary notes for all persons interviewed are provided in Appendix A.

4.2 CHEMICAL AND BIOLOGICAL ENGINEERING (CHBE)

4.2.1 CLEAN COMBUSTION LAB

The Clean Combustion Lab on the ground floor of CHBE is part of the Clean Energy Research Center. There are two engines in this lab: the first uses a 40 HP motor that normally operates at 50% load when in testing. When the engine is tested, it will normally run from 9 am to 4 pm. The engine has a dedicated 55 HP air compressor with a 2.5 kW dryer and a dedicated 7.5 HP natural gas compressor that also uses electricity when the engine is in operation. The smaller engine is 20 HP and rarely runs in coincidence with the larger engine. The lab technician interviewed estimated the engines run at 50% and 70% total load on average. Load factors for the air compressor are estimated based on the equipment's data sheet. Load factors for the dryer and natural gas compressor were assumed to be 75%. Efficiency factors for equipment have been taken from the nameplate where available, if the efficiency factor was not available, ASHRAE minimum motor efficiencies were assumed. Using the rated HP, estimated load factor, and efficiency, the *Estimated Demand Reduction* and *Probable Demand Reduction* (includes a diversity factor) are calculated as provided by the equations below.

$$Estimated\ Demand\ Reduction\ [kW] = \frac{Rated\ HP\ x\ 0.746\ x\ Load\ Factor}{Motor\ Efficiency}$$

$$Probable\ Demand\ Reduction\ [kW] = \ Estimated\ Demand\ Reduction\ x\ Diversity\ Factor$$

It is important to note that a linear relationship between rated power and load factor has been assumed in the absence of motor curves. A diversity factor is applied to this estimate to account for the probability of the specific equipment operating during a UBC peak load event. Diversity factors were estimated based on information from the engine run logs: from January 29th to July 1st, Engine 1 ran for 281 hours. On a normal test day, the engine will run from 9am – 4pm or for 7 hours/day. Thus, the number of test days is calculated as 281 hrs/7 hrs = 40 test days. There are 107 weekdays between January 29th and July 1st, thus, the diversity factor is 40 days/87 days available = 38%.

The *Estimated Demand Reduction* for the Engine Lab is 39 kW, representing 7% of peak building demand, and the *Probable Demand Reduction,* which accounts for diversity or frequency of equipment use, is 9.8 kW. Photos of equipment listed in Table 2 are given in Appendix E.

TABLE 3 - CHBE ENGINE LAB DEMEND REDUCTION

Lab	Item	Make, Model	Rated Power [HP]	Load Factor	Efficiency	Estimated Demand Reduction [kW]	Diversity Factor	Probable Demand Reduction [kW]	Duration
Clean Combustion Lab	Engine 1	Baldor, ZDM411OT-5	40	50%	94%	16	38%	6	From Jan 29-July 1st ran 281 hrs. On a normal test day engine would be run from 9am - 4pm
	Engine 2	GE, 1G136	20	70%	93%	11	38%	4	Both engines rarely run at same time
	Air Compressor w VFD	Ingersoll Rand IRN50H-CC	55	35%	95%	15	38%	6	Same as Engine 1 schedule
	CU/Dryer for Compressor	Ingersoll Rand TS1A	3.4	75%	90%	2	38%	1	Same as Engine 1 schedule
	Natural Gas Compressor	n/a	7.5	75%	91%	5	38%	2	Same as Engine 1 schedule
					Total	**49**		**18**	

4.2.2 CHBE Labs Floors 2-6

A walk through audit of all laboratories in the Chemical and Biological Engineering Building (CHBE) was completed on June 26, 2014. A number of researchers were interviewed in the CHBE labs, including graduate students and professors. Notes on feedback from the researchers in the labs are included in Appendix A. In general, most of the laboratory users could not identify any equipment they would be willing to turn off during a peak load event on campus. The majority of experiments are set up to run for several hours, some for several days, and interrupting these experiments would be significantly detrimental to their research. When asked if they were given several days notice, most researchers responded that it would significantly depend on what they were doing at that time.

One Professor, who works on a 6th floor lab mentioned he does as much as he can to reduce his energy consumption – turning off lights and computers and unplugging equipment when not in use. For the majority of laboratories visited, equipment was turned off, but remained plugged-in when not in use by the researchers.

4.2.3 CHBE Machine Shop

The Machine Shop in CHBE has a lot of high-energy consuming equipment. The Shop Manager did not think it would be possible to reschedule the use of equipment around a peak load event on campus, this is mainly because the shop is heavily relied on by graduate and undergraduate researchers. Shifting hours of operation from 7am-3pm was suggested during the days campus is expected have a peak load, however it was found that this idea is not possible as extended hours are already offered to accommodate undergraduate schedules at the end of the semester (when peak loads occur most frequently). Most students come in late morning or early afternoon for consultation, the manager noted that even if he started earlier in the morning, he would still need to work in the afternoon to accommodate these students.

4.3 PULP AND PAPER

4.3.1 PULP AND SYNGAS LAB

The two main energy-consuming labs in the Pulp and Paper building are the Pulp Lab and the Syngas Lab on the ground floor. A Research Engineer was interviewed for the Pulp Lab operation, he estimated the 150 HP, 40 HP, 10 HP motors normally operate at 60% capacity while the 7.5 HP motor usually operates at 80% load during a pulping trial. The 150 HP motor never exceeds 80 kW during trials. The diversity factor was calculated based on trials running 3 times a week, for an average two weeks out of a month, at 1.5 hours per 11 hour peak demand day. The *Estimated Demand Reduction* and *Probable Demand Reduction* are found to be 99 kW and 4 kW, respectively.

The Syngas Lab has a small motor (0.74 HP) and a 9 kW electric steam Boiler. The Boiler was said to run 12 hours a day for 1 day a week for 10 days a year at 75% capacity. The lab also uses the building's compressed air system. If both of these labs are running experiments at coincident times, it will add an estimated 111 kW of electrical demand to the campus peak, representing 64% of peak building demand. Photos of equipment listed in Table 3 are given in Appendix E.

TABLE 4 - PULP AND SYNGAS LAB DEMAND REDUCTION

Lab	Item	Model	Rated Power [HP]	Load Factor	Efficiency	Estimated Demand Reduction [kW]	Diversity Factor	Probable Demand Reduction [kW]	Duration
Pulp Lab	Motor 1 - w VSD	GE, 1F3955R	150	60%	96%	70	4%	3	15 min - 3 hrs (avg 1 hr 40 min)
	Motor 2 - w VSD	Baldor	7.5	80%	91%	5	4%	0	Runs 70 - 100 minutes per Trial
	Motor 3 - w VSD	Telco, PDH04004TE5	40	60%	94%	19	4%	1	15 min - 3 hrs (avg 1 hr 40 min)
	Motor 4 - w VSD	Ux Pro, 20FC0	10	60%	92%	5	4%	0	15 min - 3 hrs (avg 1 hr 40 min)
					Sub Total	**99**		**4**	
Syngas Lab	Motor 1	Baldor, 6DP3440	0.75	75%	86%	0.5	16%	0	12 hrs/day
	Electric Steam Boiler	unknown	12	75%	92%	7	16%	1	12 hrs/day
	Bld Air Compressor	unknown	40	10%	94%	3	16%	1	Used by Syngas Lab
					Sub Total	**11**		**6**	
					Total	**110**		**10**	

4.4 FOREST SCIENCES CENTER

4.4.1 CENTER FOR ADVANCED WOOD PROCESSING (CAWP)

The forestry building contains a large machine shop for wood processing (CAWP) and three constant climate control rooms. The lab manager was interviewed during the building walk through. He was under the impression that not running equipment during peak days is a possibility and that use of the equipment could be rescheduled as long it was not during times that undergraduate classes were scheduled. This would be easy to achieve in the summer time when machine use was low but more difficult during the school year when undergraduate students are under time constraints.

The Center for Advanced Wood Processing has a lot of large wood processing equipment in the shop as well as a large, 50 HP, exhaust dust collection system that normally runs 1-2 hours per day. Due to the quantity of equipment in the wood shop, only the machine shop equipment with a utilization factor greater than 30% was included in the calculation. The lab manager noted the shop is under the highest demand from students from January through to May and that undergraduate classes normally run from 10 am to 3 pm once or twice a week. When classes are not running, the shop has an average of 5-10 graduate/undergraduate students working on projects from 10 am to 3 pm. All students must have approval from Vincent before using the equipment.

TABLE 5 - CAWP DEMAND REDUCTION

Lab	Item	Rated Power [HP]	Load Factor	Efficiency	Estimated Demand Reduction [kW]	Diversity Factor	Probable Demand Reduction [kW]	Duration
Center for Advanced Wood Processing	Dust Collector	50	75%	95%	30	1	30	1-2 hrs/day
	Wood Shop Dust Collector Exhaust	7.5	75%	91%	5	1	5	1-2 hrs/day
	Wood Processing Lab	10	75%	92%	6	1	6	1-2 hrs/day
	Omga T55-300 – Chop Saw	1.6	75%	87%	1	30%	0.3	3-4 hrs/day
	Martin T44 – Jointer	7.5	75%	91%	5	30%	1.4	3-4 hrs/day
	Martin T54 – Planer	7.5	75%	91%	5	30%	1.4	3-4 hrs/day
	General S 350 – Table Saw	3	75%	90%	2	30%	0.6	3-4 hrs/day
				Total	**52**		**44**	

4.4.2 COLD ROOMS

Three climate-control rooms are used to store wood used for experiments at a constant temperature and humidity level. Unlike the bio and chemical control rooms, it is possible to turn these units off for a short period of time (ie 1 day) without significant adverse effects on the experiment. The issue with turning them off is that it is not easily administered, and they have had issues in the past operating the units correctly again once they are turned on. The Lab Manager also mentioned there could be push back from researchers to shut these off.

4.4.3 FISH LABS

The fish labs in Forestry run all year round. The lab has three 0.5 HP compressors (coolers) and 2 small pumps. The 2 pumps run continuously and are used for the filtration system. If they are turned off the fish will die. Compressors run from May to November for the salmon eggs and are essential for salmon egg survival. The fish lab is connected to the backup UPS.

4.4.4 CHEMICAL/WET LABS

Generally speaking, the same challenges were found in these labs as in the CHBE 2-6th floor labs in that the labs had small, distributed loads. The Senior Technician, who oversees all of the chemical and wet labs in Forestry, was not optimistic about the inclination of researchers rescheduling or delaying laboratory operations during a peak load event on campus.

4.5 MICHAEL SMITH LABS (MSL)

Most of the equipment in MSL consists of small, distributed loads ranging from 0.5 – 2 kWs, including: biosafety cabinets, centrifuges, freezers, fridges, incubators, ovens, shakers, and autoclaves. The freezers, refrigerators, autoclaves, and ovens were found to consume the most energy. Freezers and refrigerators are essential for laboratory operations and cannot be turned off, for this reason only autoclaves and ovens were looked at in greater detail. There are 5 wall-mounted and 2 bench-top autoclaves in MSL that normally operate once per day. Together, they are estimated to consume 262 kW of electrical energy when in use. Two ovens are estimated to consume 3 kW of electrical energy when in use. Combined, this equipment will add 282 kW of electrical load to the building if all running at the same time. The laboratory manager noted the autoclaves and ovens could each run for 1 hour per day.

TABLE 6 - MSL DEMAND REDUCTION

Item	Model	Rated Power [kW]	Load Factor	Eff	Quantity	Estimated Demand Reduction [kW]	Diversity Factor	Probable Demand Reduction [kW]	Duration
Wall Mounted Autoclaves	Steris AMSCO Century SV-136H	5	80%	98%	4	16	25%	4	1-3 hr /cycle, No. of cycles per day varies widely
	2X Steris CH10-891-500 2X Steris CH08-891-500	75	80%	98%	4	245	25%	61	Starts-up in morning and cycles on when Sterilizer is on
	Steris AMSCO Century SV-160H	1.5	80%	98%	1	1	25%	0	20 min -1 hr /cycle, No. of cycles per day varies widely
Benchtop Autoclave	Market Forge	12	70%	98%	2	17	25%	4.3	20 min -1 hr /cycle, No. of cycles per day varies widely
Ovens	GCA/Precision Scientific 31542	1.62	80%	98%	1	1	25%	0.3	20 min - 3 hrs
	Yamato DX600	1.5	80%	98%	1	1	25%	0.3	
					Total	**282**		**71**	

4.6 CIVIL AND MECHANICAL ENGINEERING (CEME)

4.6.1 MACHINE SHOPS

The machine shop in the civil and mechanical engineering building is expected to contribute up to 31 kW of peak demand to CEME building electrical load. However, due to the timing pressures of the undergraduate students who use the machine shop, it is very unlikely the shop can reschedule the use of its equipment, especially during second semester when the machine shop is busiest.

TABLE 7 - CEME MACHINE SHOP DEMAND REDUCTION

Lab	Item	Rated Power [HP]	Quantity	Load Factor	Efficiency	Estimated Demand Reduction [kW]	Diversity Factor	Probable Demand Reduction [kW]
Machine Shops	Standby Compressor (fixed speed)	45	1	20%	94%	7	20%	1
	TRIUMPH 2000 lathe	7	3	50%	90%	9	50%	4
	Colchester Master 2500	5	2	50%	90%	4	5%	0
	Mecnoimpex	3	1	50%	90%	1	5%	0
	Johnson V-36	3	1	50%	90%	1	5%	0
	King	2	1	50%	87%	1	5%	0
	Drilling Machines	0.75	4	50%	86%	1	5%	0
	Milling Machine 1	5	1	50%	90%	2	5%	0
	Milling Machine 2	3	2	50%	90%	3	50%	1
	Milling Machine 3	2	1	50%	87%	1	50%	0
	Water Jet Cutter	20	1	50%	93%	8	50%	4
	VF4 CNC Milling Machine	15	1	50%	93%	6	5%	0
	CNC Lathe	15	1	50%	93%	6	50%	3
	White CNC Mill	12	1	50%	92%	5	50%	2
	Small Lathe	1	1	50%	86%	0	50%	0
	Blue Lathe	5	1	50%	90%	2	50%	1
	Main Building Compressor	60	1	50%	95%	24	50%	12
					Total	**81**		**31**

4.7 HENNINGS (PHYSICS BUILDING)

Two lab managers were interviewed in the Physics Building. With the exception of two milling machines in the basement, the majority of laboratory loads in this building are small (0.1 – 1 kW). The machine shop in basement has a CNC machine (14 kW) and a welding machine that is rarely used. The CNC machine is used up to a couple of hours a day and is needed on demand for when items break.

4.8 Specific Laboratory Equipment

4.8.1 Lasers

There are a number of high-powered lasers at UBC in the kW power range. However, these high-powered lasers often operate at the lowest possible power draw during experiments for safety reasons, and it was found that these loads are mostly infrequent as stated by Richard Colwell, who works for Risk Management Services, Sheldon Green, a Professor in the Mechanical Department, and Randy Deane who works in MSL.

4.8.2 Refrigerators, Freezers, and Cold Rooms

There are a number of fridges, freezers, and cold rooms in the UBC buildings audited, and it is worth reviewing this laboratory equipment in a dedicated section. Freezers and cold rooms, especially those operating at -80C, consume a significant amount of energy. The cold areas are used to store the specimens used for laboratory research at specific temperature. Most of the cold rooms and -80C freezers are on backup uninterruptible power supply (UPS) and are unavailable for load scheduling. The only exception to this are the Forest Sciences cold rooms as previously discussed, however it is not recommended they be turned off during peak load due to complications of running them properly again. -80C Freezers are used for cryopreservation of tissue samples and the temperature set point is specific to preserving tissues for 1-2 years.

4.8.3 NMR Machines

There are quite a few NMR (Nuclear Magnetic Resonance) instruments on campus. These machines range from 1 to 10 kW in power draw for computer and controls. The magnets themselves require charging once every few years, and the newer instruments almost never require recharging. The NMR machines in the Chemistry buildings are under very high student demand. To resolve this, a scheduling system was set up online where students can reserve time with the instrument. It was noted by a lab manager at Risk Management that rescheduling these loads would prove difficult due to the instrument's high utilization rate.

4.8.4 Compressed Air

Most buildings visited have at least one central compressed air unit dedicated for laboratory use. Table 7 gives the rated power draw of these central air compressors. Combine, their rated power is 332 HP or 248 kW which could be a significant contribution to Campus peak load. Because the compressed air is used in multiple labs throughout the building, it would be difficult to coordinate use of compressed air. An awareness message could be broadcasted during a peak load event notifying laboratory and workshop users to delay the use of compressed air for the duration of the peak load event.

TABLE 8 - LABORATORY AIR COMPRESSORS

Building	Model	Rated Power [HP]	VSD	Quantity	Efficiency	Total HP
Michael Smith Labs	Powerex PE-OPP54-2400-LAL	15	No	1	93%	15
Chemical & Bio. Eng.	Ingersoll-Rand SSR-HP75	75	No	1	95%	75
	Atlas Copco XT50 VSD	67	Yes	1	95%	67
Forest Sciences	Quincy OMT20	20	Modualting	1	93%	20
	Hitachi Model #OHT-15TDX	15	unknown	2	93%	30
Pulp & Paper	Quincy QSB40	40	No	2	94%	80
CEME	Atlas Copco GX11 P	15	No	2	93%	30
Physics (Hennings)	Quincy 370 LVD	15	No	1	93%	15
Total					**Total Capacity**	**332**

CHAPTER 5

5.0 RECOMMENDED PILOT PROGRAM

5.1 INTRODUCTION

Based on the information gained through the building audits and literature review, a pilot program is outlined in this Chapter. The recommended pilot program will focus on low-cost or no-cost measures focusing on behavior change from faculty and staff. Based on this assumption, the pilot program will incorporate strategies proposed by McKenzie-Mohr's community-based social marketing approach. These strategies include: commitment, social norms, social diffusion, prompts, communication, incentives, and convenience. A five step process is identified in the community-based social marketing approach as: 1) Selecting behaviours, 2) Identifying barriers and benefits, 3) Developing strategies, 4) Piloting, and 5) Broad scale implementation and evaluation (McKenzie-Mohr, 2011). This approach defines the structure for the pilot program in the following sections.

5.2 SELECTED BEHAVIOURS

The behaviours selected for study in the pilot program are listed below. They include laboratory specific behaviours, but also campus wide staff behaviours. It is recommended that the pilot program have three approaches: 1) targets specific labs, 2) targets specific buildings, 3) targets all faculty and staff.

Laboratory Specific Initiatives for Duration of Peak Load Event:

- Delay the use of Autoclaves, Ovens, Dishwashers until after 4pm.
- Close Fume Hoods.
- Avoid opening refrigerators, freezers, and cold rooms for extended periods of time.
- Delay the use of equipment that uses compressed air.
- CHBE Engine Labs: Delay trial runs/test of engines.
- Forest Sciences CAWP: Delay the use of wood shop equipment.
- Pulp & Syngas Lab: Delay trial runs.

Campus Wide Initiatives for Duration of Peak Load Event:

- Turn off all unnecessary electronic devices.
- Turn off laboratory equipment not currently in use.
- Turn off computer monitors, copiers, and printers.

- Work from battery power on laptops.
- Turn off all non-essential lights and use energy efficient task lighting.
- Set back thermostats.
- Close windows and shades.
- Schedule high-energy use meetings or events in the morning rather than the afternoon.

5.3 HYPOTHESIZED RESULTS

Estimated results of the pilot program for the Laboratories audited were presented in Table 2: that is, approximately 5% of building peak load can be reduced from rescheduling laboratory equipment use, resulting in at least $2,722 of total demand charge savings and 143 kW of peak load reduction for September, November, and December peak load months. Extrapolating the probable demand reduction using the total UBC Vancouver laboratory floor area given in Table 1, the expected demand reduction is 976 kW, or 1.8% of campus peak demand in 2013. This equates to $6,198 in demand charge savings per billing period and $18,594 per annum. This assumes demand reductions in peak months of September, November, and December.

It is important to note the estimated demand reduction will also help contribute to a possible delay in electrical infrastructure upgrades, resulting in further costs savings to UBC. For example, Rampley's 2010 SEEDS report found that a peak demand management program reducing 5% of campus peak load would delay transmission capacity by three years (from 2030 to 2027), and result in deferred transmission upgrade cost savings of $824,951 (Rampley, 2010). This estimate assumed a 6% discount rate and discounted from 2027, 2028, and 2029 to 2010 dollars.

5.4 BARRIERS AND BENEFITS

From the information gathered during the laboratory audit there are a number of important items to consider in the development of a pilot program:

- It is the mandate of the University to conduct research and serve the undergraduate and graduate researchers. This means use of laboratory equipment to conduct research is a priority and that rescheduling will need to be voluntary to minimize impact on campus research.
- The majority of researchers and professors interviewed were unwilling to reschedule research around a peak load events due to time pressure, safety, as well as a high utilization factor on some equipment.
- Because so few laboratories have the flexibility to schedule around campus peak load events, it might be best to target these labs directly.

Table 9 summarizes the barriers and benefits to program participants and UBC. The main barrier identified to program participation is that there is no direct benefit to researchers to reschedule experiments around peak load events, in fact, participating in the program could penalize and delay research. In other words, the incentives are misaligned. A number of strategies to increase faculty and staff in program participation are discussed in the next section.

TABLE 9 - COSTS AND BENEFITS TO PARTICIPANTS

Entity	Benefits	Costs and Barriers
Laboratory Participant	- "Feel Good" - Incentives?	- Continued inconvenience - Research is penalized
UBC	- Reduced Demand Charges - Increased Capacity - Avoided/deferred infrastructure costs - Reduces Price Volatility	- Initial Costs in implementing response plan (marketing, administration) and required technology - Incentive payments - Post evaluation costs

5.5 Strategic Approach

5.5.0 Pilot Plan

Based on the combined findings from the literature review, laboratory audits, interviews, and application of the McKenzie Mohr approach, the pilot program illustrated in Figure 7 is proposed for a demand response plan.

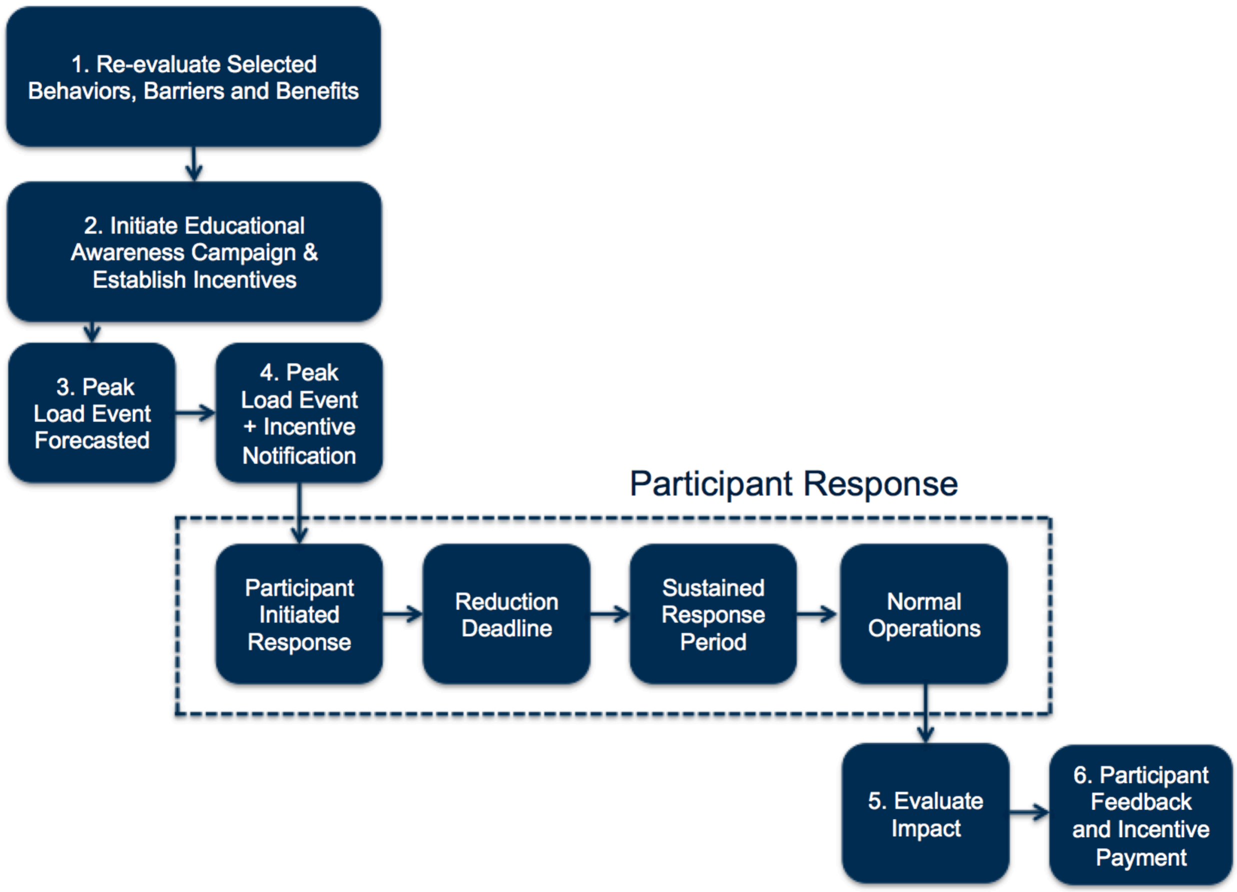

FIGURE 9 – BEHAVIORAL DEMAND RESPONSE PILOT PLAN

5.5.1 Re-evaluated Selected Behaviors, Barriers and Benefits

Based on the targeted laboratories or buildings, it is advisable to re-visit the first two steps of McKenzie Mohr's approach to ensure targeted behaviors are selected appropriately. Also to ensure that the barriers and benefits are still applicable and none have been missed for specific buildings or labs that were not audited as part of this study.

5.5.2 Initiate Educational Awareness Campaign & Establish Incentives

Because implementation of the demand response program will involve initial capital costs as well as ongoing costs from UBC, education of building occupants on the program benefits is recommended to encourage participation and increases the likelihood of a successful program. It is also worthy of note that many case studies report low program penetration rates (Albadi et al., 2007). The problem of program participation for most programs was thought to be a product of poor marketing and limited technical assistance (Albadi et al., 2007).

As a first step to increasing program participation an educational awareness campaign explaining the program and, more importantly, why staff and faculty should participate should be administered. This will establish social pressure and create social norms, increasing program participation. The awareness campaign should be simple, quick to read, and explain the campus peak load issue as well as any incentives participants will receive.

The following items are recommended for the educational awareness campaign:

- Posters to distribute to buildings on campus, similar to those distributed at Harvard University, see Appendix B.
- A website dedicated to the program to complement campus advertising.
- Due to the timing of peak load events on campus, the educational awareness campaign should be executed by late summer to early September.

Consideration should also be taken on the type of incentive system used to promote participation. In order to gain support from research staff to reduce consumption during peak load events, the following incentives are proposed:

- Peak load reduction contest. Similar to the "Shut the Sash" fume hood contest, this would target specific buildings that have a significant amount of laboratory operations or plug load use. In anticipation of a peak load event on campus, a message could be broadcast to these buildings to see which building could reduce the most below their previous years building peak load contribution.
- Contact a firm that specializes in Employee Engagement such as Nudge Rewards or Achievers. These firms use mobile apps to increase program participation, track, and reward employees who are participating.
- Direct financial incentive. Incentive based demand response programs pay participants to reduce their loads at requested times (DOE, 2006). This is not recommended until after a successful pilot program has been implemented and a study with a control group is recommended to determine if a financial incentive will help or hinder the DR program. It could potentially have adverse effects; if people are paid to reduce energy, perhaps they will feel justified in consuming more energy when there is no financial incentive (U. Gneezy et al., 2011).

5.5.3 Forecast Peak Load Event

The University of British Columbia will need to invest in tools that will forecast, dispatch, manage, measure and verify the effectiveness of demand response and chosen measures, as indicated in the scope of work document for UBC's Demand Response and Measures to address BC Hydro Transmission constraints (EQL Energy, 2014). Peak load forecasting as indicated by the demand response scope of work will be utilized for the pilot program to determine the occurrence of a peak load event on campus.

5.5.4 Peak Load Event & Incentive Notification

Once a peak load event is forecast, an alert message should be broadcast to targeted laboratories and staff. Laboratories are normally required 7 days advanced notice of any mandatory interruption to experiments (for maintenance reasons), however because the program is voluntary, 1- 3 days will suffice. The following points should be considered for the notification message:

- Notification via email, text message, or mobile app.
- Notification should specify date and duration. Ie: from 9am to 4pm on December 9th
- Notification should give incentive (ie why should faculty and staff participate?)
- Notification should be specific to selected behaviors.
- Appendix C gives an example of the Welland Campus demand response alert message.

5.5.5 Evaluate Program Performance

The demand reduction from the pilot program should be quantified in order to validate its effectiveness and provide feedback to program participants. The following sections give detailed explanation on the best method to determine peak demand savings for each target group.

1) Measuring Laboratory Performance

It is impossible to measure peak demand reduction for specific laboratories without the use of data loggers or individually metered electrical panels. The easiest solution to determining the effectiveness of a behavior change demand response program on targeted labs is to conduct a post event survey of the researchers and staff who use the labs. It is important to note that survey questions targeted by behavior based programs may be prone to exaggeration or error by the respondent as noted by some Evaluation, Measurement, and Verification Programs and that surveys used for evaluation can also be subject to lower response rates and selection bias (A. Todd et al., 2012).

2) Measuring Building and Campus Wide Performance

For buildings where all laboratories, faculty, and staff are targeted in the pilot program, it is best to measure the demand reduction directly following either the CEATI Demand Response Reference Guide, or IPMVP Option C: Whole Facility Measurement. The IPMVP recommends that savings should typically exceed 10% of the baseline energy in order to confidently discriminate the savings from the baseline data (EVO, 2008). Based on the results of the laboratory study, it could be difficult to obtain 10% savings at the building level depending on participation levels from all faculty and staff.

The *CEATI Demand Response Reference Guide* outlines a two-step process to quantify performance for peak demand reduction in buildings: 1) Estimate the business as usual demand or the baseline scenario and 2) measure the demand reduction against this established baseline. To estimate the baseline scenario, an hourly demand curve for the peak load event can be determined using average demand for each hour on prior days (CEATI International, 2010). The baseline is constructed using recent average peak demand; the CEATI Demand Response Guide describes, "using the 3 to 10 highest consumption days out of the 10 working days immediately preceding the event day." The baseline is established through projected energy use in a business-as-usual case and includes any necessary modifications for weather or other factors (CEATI International, 2010). An example from the reference guide is provided in Appendix D.

5.5.6 PARTICIPANT FEEDBACK AND INCENTIVE PAYMENT

The final step in the demand response pilot program is to provide feedback on the impact and give any incentive payment to program participants. This will help encourage participation in the next demand response event.

CHAPTER 6

6.0 CONCLUSIONS

This section summarizes the key findings of the study and provides recommendations for future research related to the proposed UBC Pilot Program and demand reduction opportunities for the Vancouver Campus.

6.1 KEY FINDINGS

Frequency and Duration of Campus Peak Load Events

From the peak demand analysis provided in Chapter 3, it was found that peak demand days, where electrical demand from the Vancouver campus exceeds 45 MVA, occurred 61 days of the year in 2013. Due to the frequency of occurrence, reducing annual peak demand below 45 MVA via a behavioral change demand response program is unlikely and implementing the program 61 days of the year is fairly substantial. Based on the cumulative load frequency curve, it was seen that the frequency of occurrence of peak load drops significantly above 46.5 MVA; only slightly above the 45 MVA threshold. Only ten days in 2013 did electrical demand exceed 46.5 MVA. It was found that the duration of electrical demand above 46.5 MVA are a full day, generally from 8:30 am to 7:00 pm. These days occur most often in September, November, and December months of the school year.

Laboratory Peak Demand Reduction

Of the six buildings audited, only four laboratories were identified to have significant equipment loads (defined as greater than 10 HP) that could be rescheduled during a peak load event on campus. The four labs identified could reduce peak load contribution by 143 kW, resulting in $2,718 of total Demand Charge cost savings over the September, November, and December billing periods. These loads were found to represent approximately 5% of each building's peak load. While this is a relatively small result in terms of kWs, when extrapolated to all academic buildings on Campus with laboratory space, this results in 976 kWs of electrical demand reduction and $6,198 in demand charge savings per billing period. It is important to note that this estimate is extremely conservative and includes both load factor and a diversity factor on equipment use. This estimate also excludes any demand reduction by other faculty and staff included in the behavior change pilot program.

Behavior Change DR Pilot Program

Based on the laboratory audit, interview results, and a comprehensive literature review, a Pilot Program is recommended for reducing occupant and laboratory peak load contribution. The pilot program suggests targeting three groups for study: 1) specific laboratories, 2) specific buildings, 3) Campus wide faculty and staff to determine which approach is most effective. It is anticipated that faculty and graduate student participation levels in laboratories will be low due to specific constraints cited by those interviewed including: time constraints on researchers, safety of researchers and laboratory staff, high utilization factor of equipment, and experiments already in progress, and the life cycle of research organisms. The key steps of the pilot plan are presented in Figure 9.

6.2 DIRECTIONS FOR FUTURE RESEARCH

Based on the findings from the audit and interview study, the most pertinent item for future research is determining the most effective incentive program to encourage faculty and staff engagement in the pilot. The main barrier identified to program participation is that there is no direct benefit to researchers and staff to participate in the program. In fact, participating in the program could penalize and delay research. In other words, the incentives are misaligned. A number of strategies for encouraging participation are presented in the strategic approach and a recommendation is needed on which method will be most effective.

From the building audits, compressed air for laboratory use was identified to be a significant point source load in all buildings, with a total capacity of 332 HP in the six buildings audited. Some of the compressed air systems were found to have VSDs while others do not. It could be worth investigating whether VSDs are an appropriate measure for laboratory compressed air, identifying how often and at what load factor the compressed air units run, and whether there are any opportunities for scheduling or load shedding.

Finally, future research should include implementation of the pilot program and measuring program performance for each target group identified.

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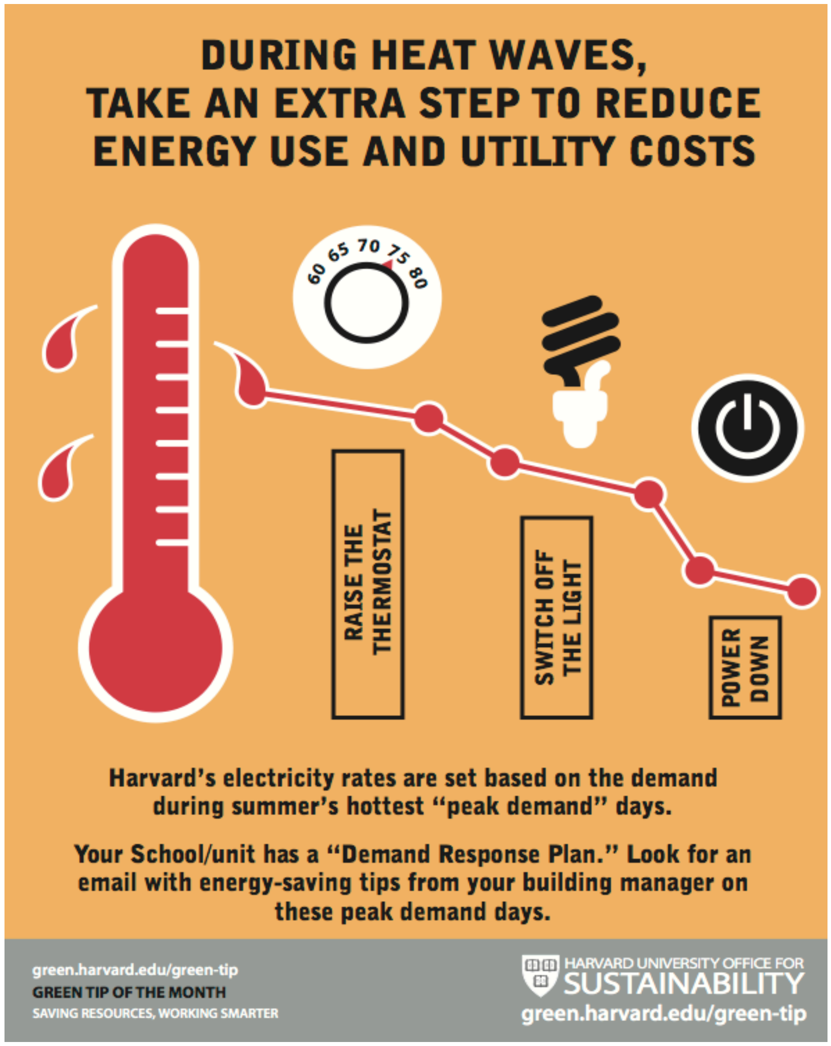
APPENDIX A – INTERVIEW RESULTS SUMMARY

Building	Position	Laboratory	Findings
Michael Smith Laboratory	Facility Manager	All	Could be a possibility for rescheduling usage of autoclaves and ovens in building
Michael Smith Laboratory	Lab Manager	Heiter Lab	Mostly small distributed loads 0.5 - 2 kW
Chemical & Biological Eng.	Lab Manager	All Labs (except G/F)	Little opportunity found for rescheduling loads in labs on floors 2-6 of CHBE
Chemical & Biological Eng.	Engineering Technician	Test Cell Labs	Could be possible to reschedule around peak load events in these labs if given enough notice (3-7 days, ideally).
Chemical & Biological Eng.	Lab Manager	All	Of the opinion that most labs would find rescheduling loads difficult due to research pressures and time constraints.
Chemical & Biological Eng.	Professor	CHBE 608	Already does his best to reduce energy consumption in the lab he works in in CHBE. Computers, equipment, and lights are turned off when he leaves and he turns off monitors when leaving the lab for a small period of time. Most of the time it would not be possible run experiments during peak load events on campus.
Chemical & Biological Eng.	Graduate Student	Fuel Cell Lab	Would voice an official complaint with his department head. Graduate students get paid very little and have a high regard for research; students have the right to use the research resources.
Chemical & Biological Eng.	Technical Supervisor	Machine Shop	The Machine Shop is heavily used by undergraduate and graduate students. Did not think it would be at all possible to reschedule the use of equipment around a peak load event on campus.Shifting hours of operation from 7am-3pm was suggested during the days campus is expected have a peak load, however this idea is not possible as extended hours are already offered to accommodate undergraduate schedules. Most students come in late morning or early afternoon for consultation, noted that even if he started earlier in the morning, he would still need to work in the afternoon to accommodate these students.
Chemical & Biological Eng.	Professor	Bio Energy Labs	Laboratories would likely do what was easy but would be unlikely to inconvenience their research. Not possible to reschedule at during morning or evenings due to safety reasons.
Pulp and Paper	Research Engineer	Pulp Lab	There is a possiblity to reschedule use of equipment around a peak load even on campus if given enough notice. 3-7 days advanced notice would be preferred
Pulp and Paper	Associate Professor	Syngas Lab	There is a possiblity to reschedule use of equipment around a peak load even on campus if given enough notice. 3-7 days advanced notice would be preferred
Civil & Mech Engineering	Lecturer	Machine Shops	Very little opportunity to reschedule undergraduate and graduate use of the equipment, especially during time pressures of 2nd semester.
Forest Sciences	Graduate Student	Fish Labs	Not possible to turn off without fish and fish eggs dieing
Forest Sciences	Professor	NMR Machine	NMR machine uses less than 10 kW of energy. Usually in high demand and rescheduling would interrupt research.
Forest Sciences	Facility Manager	CAWP	There is a possiblity to reschedule use of equipment around a peak load even on campus.
Forest Sciences	Senior Technician	All Wet Labs	Little opportunity found
Physics Hennings	Electronics Lab Manager	Electronics Labs	No opportunity for load reductions found in laboratories due to insufficient load size
Physics Hennings	Technical Services Director	All	
Chemistry Blocks	Lab Manager	All	Did not think the Chemistry Blocks were good candidates for this study due to the nature of the experiments ongoing and time constraints. Was fairly pessimistic regarding voluntary behaviour change initiative.
n/a	Lab Manager	All	Based on experience working with the laboratories at UBC, was of the opinion that a DR behaviour change program would be difficult to implement.

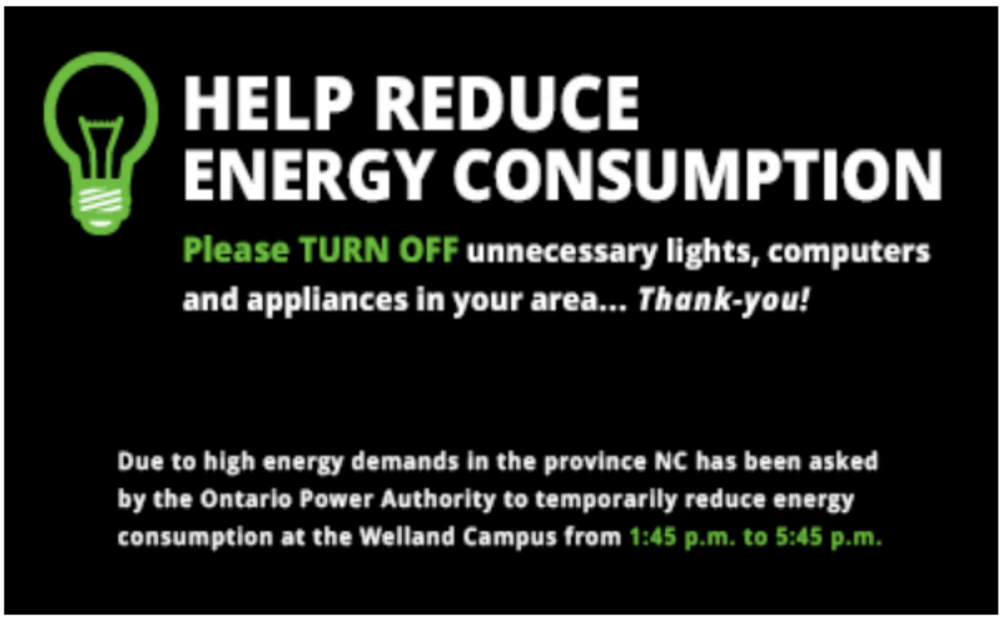
* Names and contact information are not present for confidentiality purposes

APPENDIX B – HARVARD ENERGY AWARENESS POSTER



(Harvard University, 2013)

APPENDIX C – NIAGARA/WELLAND COLLEGE DR ALERT MESSAGE



(Niagara College, 2013)

Appendix D – CEATI DR Reference Guide: Baseline Calculation

"As an example of how a baseline is constructed, consider a program using a "3 in 10" baseline with a day-of adjustment: The utility calculates an average demand for each hour, using the hottest 3 days out of the past 10 weekdays prior to an event (excluding event days and holidays). This value is then adjusted by using a ratio of the average load of several hours before the event to that of the same hours from those 10 weekdays. The result is compared with the amount of energy being used on the event day, which can be used to adjust the baseline.

So let's say a business used 1 megawatt during the hours of 2:00 p.m. and 5:00 p.m. on the 3 hottest days of the past 10 working days. The baseline energy use for that business—the expected demand for energy on the afternoon of the next day—would be 1 megawatt. When an event is called the morning of the next day, the utility or DR provider would take into consideration energy use on the day of the event and make a day-of adjustment: The event is to take place from 2:00 to 4:00 p.m., but that day is unusually hot, and the business is using 1.1 megawatts between noon and 2:00 p.m., just prior to the event. So the baseline would be adjusted upwards by 0.1 megawatts, raising the level of compensation.

A similar adjustment can be used to reduce a business' baseline (a downward adjustment) if energy use just before an event is lower than expected. Because some facilities need time to ramp down their equipment and processes before a DR event, the day-of demand measurement will often be taken an hour or more before the actual event rather than right before an event. This delay between establishing day-of demand and the actual event permits facilities to start their shutdown procedures just before an event, without being penalized by a downward adjustment in their baseline. Talk with your utility or DR provider about compensation for different programs, and what kind of baseline will be used."

(CEATI International, 2010)

APPENDIX E – PHOTOS OF SPECIFIED LABORATORY EQUIPMENT

Photo 1 – CHBE Engine 1

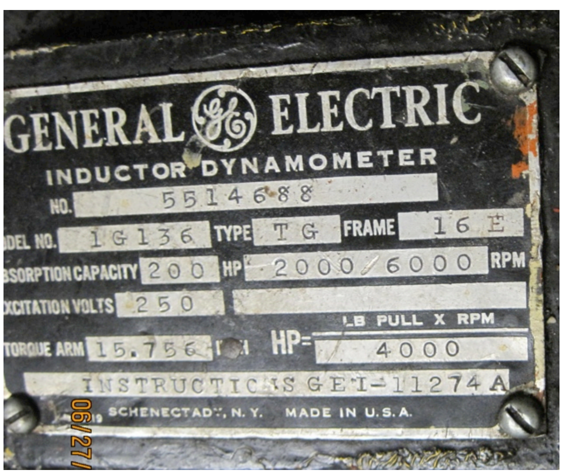


Photo 2 – CHBE Engine 2

Photo 3 – CHBE Engine Air Compressor

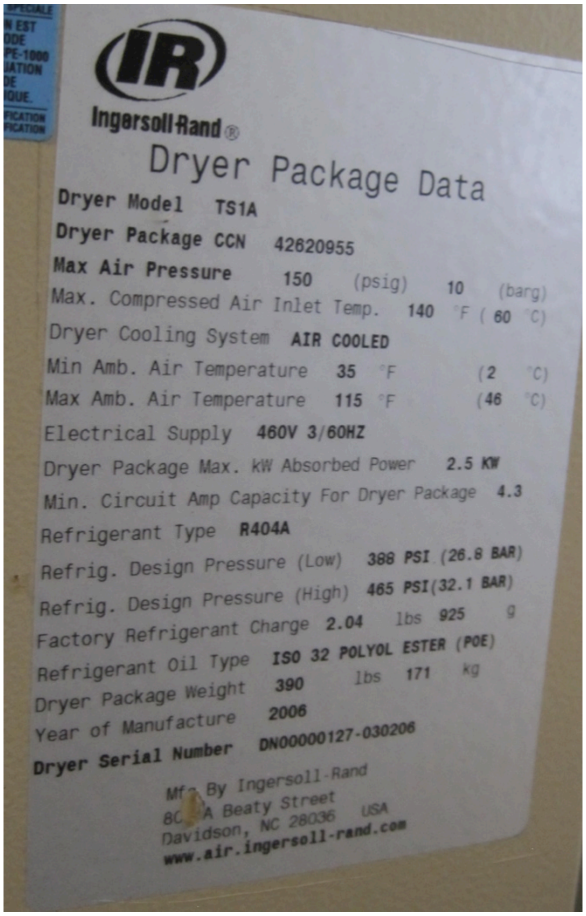


Photo 4 – CHBE Compressed Air Dryer

Photo 5 – CHBE Natural Gas Compressor

Photo 6 – Pulp Lab Motor 1

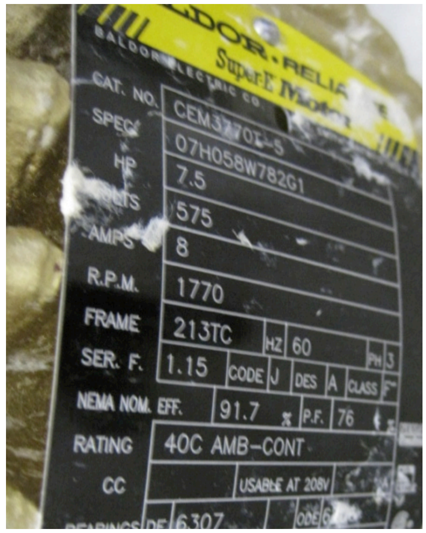


Photo 7 – Pulp Lab Motor 2

Photo 8 – Pulp Lab Motor 3

Photo 9 – Pulp Lab Motor 4

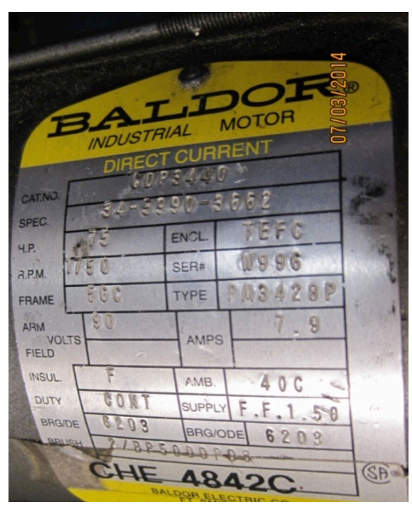


Photo 10 – Syngas Lab Motor 1

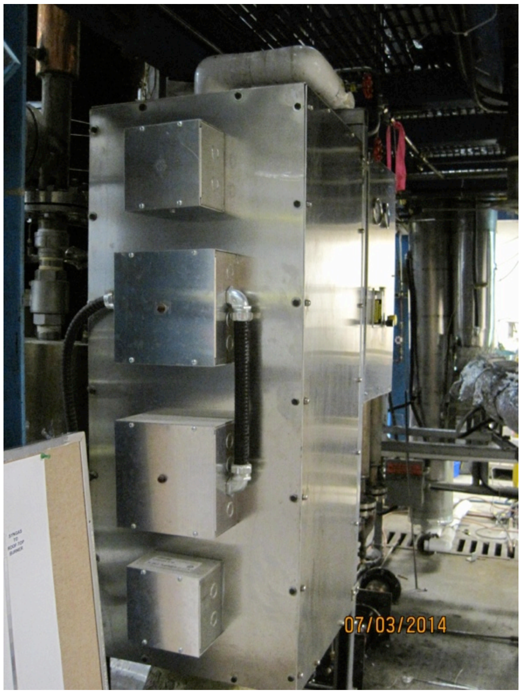


Photo 11 – Syngas Lab Electric Steam Boiler

Photo 12 – Pulp & Paper Building Air Compressor

Photo 13 – MSL Wall Mounted Autoclave

Photo 14 – MSL Benchtop Autoclave

Photo 15 – MSL Oven