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Dr.Xiotao Bi
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Vancouver, BC
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Re: SEEDS Project for CHBE 484 titled, “Green Labs - Energy Conservation and Management Techniques.”

Dear Dr. Bi,

Please find attached the report titled ‘Green labs - Energy Management’ for your review. The project was conducted during our course numbered CHBE 484 titled Green engineering. The group consisted of Mankaran Singh, Abin Antony and Shruti Kapoor.

Currently, many research labs on campus use older outdated equipment that take into account minimal considerations for energy usage. This project examines the impact of older, less energy efficient equipment and analyses the equipment to see if replacement, maintenance or nothing should be done with the various equipments. This project was conducted with the aim of reducing the green house gas emissions, while keeping cost in mind. The findings from this project have been enclosed and presented in this document below.

This project would not have been possible if it were not for help from both staff in the Chemical and Biological Engineering building and the U.B.C sustainability office and we would like to extend a sincere thanks for all their patience and help.

Sincerely,

Mankaran Singh, Abin Antony, Shruti Kapoor

CHBE 484 Green Labs - Energy Conservation and Management Techniques for Laboratories

Abin Antony
Shruti Kapoor
Mankaran Singh

April 15, 2009

Executive Summary

Seven labs in the Chemical and Biological engineering building were audited and power consumption data was gathered for each lab using a kill-a-watt meter. The meter took readings for current, power, frequency and voltage. Based on these readings, several equipments such as stirring hot plates, centrifuges, ovens, water baths, and small instruments were audited.

For stirring hot plates, it was found that the hot plate in the undergraduate lab needs to be replaced since it had the highest power consumption rate at 1146 W and visible fouling. An LCA analysis found that if the hot plate was replaced by a new one costing $540, the cost would be reclaimed within 5 years.

For centrifuges, the biological research lab had the highest power consumption and this was due to the throughput size. It was found that revolution speed and throughput were the most significant factors for energy usage. The centrifuge was a new model and was deemed to not be replaced. For water baths, it was found that the undergraduate and water pollution labs consume the most energy. The reason was determined to be poor insulation; preventative maintenance is recommended.

Vacuum ovens audited in the lab were found to be adequate and hence no replacement is required. The gas chromatogram in the laboratory was found to consume 122 W of electricity during operation. However, it has a short operating time and a high capital cost and was found suitable. Computers were found in all the labs and were found to consume approximately 93 W each. New models have about the same consumption and hence no replacement was needed.

From the audits that were conducted, it was found that all the equipment consumed some form of energy when plugged in, regardless of being in operation or not. It was hence deemed that staff should ensure all equipment is unplugged when not in use and lights and ventilations should be turned off. If all these recommendations are followed, U.B.C should be able to become closer to being carbon neutral by 2010.

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Theory

The University of British Columbia is western Canada’s only academic program bringing together students, faculty and staff in projects that address sustainability issues. Initiated in 2001, the SEEDS project has saved the university hundreds of thousands of dollars and attracted more than 1000 participants. This project is part of the SEEDS program and is aimed at conducting research that will contribute to the content of an on-line virtual green research lab tool. This tool is expected to be part of the U.B.C Green Research Initiative and will allow the public to obtain online information regarding equipment, materials and practices that will assist research personnel to reduce their environmental impact.

One of the major issues that UBC is dealing with is the B.C provincial government to be carbon neutral by the year 2010. Based on a per capita basis, B.C is one of the lowest GHG emitters in North America and is ranked the second lowest after Quebec in the GHG emissions per person. B.C’s emissions have been steadily increasing since 2004.

In 2004, B.C.’s emissions intensity was 15.9 tonnes CO_2 per capita; almost one-third below the national average of 23.7 tonnes. The predominance of hydroelectricity in the provincial generation mix is the main reason for our relatively low per capita emissions.

In light of BC’s GHG emissions in the year 2006, it is evident that about 12% are contributed from residential and commercial activities. The figure below shows the break- up of the GHG contributors:

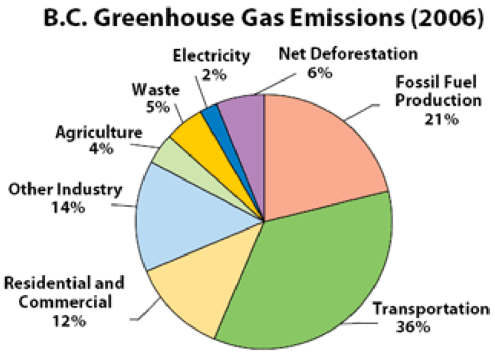


Figure 1- BC's GHG emissions

As per the BC government's mandate, U.B.C is expected to be carbon neutral by 2010 meaning that for every ton of CO2 generated, U.B.C shall pay $25 for a potential impact of over $ 4 million a year. One of the preventive measures taken by the university is that of retrofitting buildings to reduce emissions and curb its electrical energy use. U.B.C, being a premier in research and development, has extensive laboratory and bench scale labs to conduct experiments.

Energy efficiency has proved to be a cost-effective strategy for building economies without necessarily growing energy consumption. One way to reduce the energy consumption is to use more energy efficient equipment which utilizes the best of technology. Still, efficiency often has taken a secondary position to new power generation as a solution to global warming and creating national energy policy.

Lab facilities use a considerable amount of energy resources. The amount of energy consumption, raw materials and other lab testing products are a factor in the overall competitions of industries utilizing laboratory type facilities. Although there exists a great potential for saving considerable amounts of energy, improving the energy saving in a lab setting is no easy task. Purchase of new equipments takes a lot of investments and isn't always feasible for the companies/professors/institutions conducting the research due to limited nature of funds available. The importance and value of the activities conducted in laboratory-type facilities is that they represent one of the most powerful contexts in which energy efficiency improvements can decrease the energy consumption substantially.

This project is aimed at the estimating the amount of energy that can be saved by either replacing the old apparatus by new, more energy efficient apparatus that will give the same quality of work.

Methodology

The main aim of this project is to provide knowledge and tools for increasing the energy efficiency and performance of new and existing laboratory-type facilities at the University of British Columbia. The project was approached in a systematic fashion by exploring consisting of two avenues: (1) identification of current energy use and savings potential and (2) Assessing energy saving by implementing new and improved equipment and apparatus for research.

The methodology followed was fairly simple. The first step was to get an understanding of the labs setup at the Chemical & Biological Engineering (CHBE) building located at U.B.C Vancouver campus. The department of Chemical and Biological engineering conducts various types of research such bio-monitoring, pollution prevention and process control. An engineered assumption for this project is that the amount of energy consumed by a refrigerator or any other appliance will be the same throughout the university and will not be dependent on its location on campus.

Before starting each lab analyses, a hazard assessment was conducted prior to initiating the lab analyses. Its purpose is to anticipate, as much as is reasonable, any hazards or hazardous conditions that are inherent or could arise out of the duration the analyzes were conducted. Once the hazards have been identified, the controls for eliminating or minimizing these hazards can then be determined and implemented.

In total, seven labs were conducted. The equipment analyzed were located in the Rheology lab, Catalysis Research lab, Water Pollution Control lab, Fuel Cell Research Lab, Sensor Lab, Undergraduate laboratory and Biological Research laboratory.

For the lab analyses, a “kill-a-watt” meter was loaned from the library for collecting the energy consumption. A picture of the kill-a-watt meter is shown in Figure A1 in Appendix A. This Kilowatt-hour meter is easy to set up and use. It gives the power usage information for individual appliances, displaying true power consumed (including power factor information), and keeps track of cumulative kilowatt-hours and cumulative time the meter has been plugged in.The kill-a-watt meter was used for measuring the Voltage, Current, Watt and Frequency.

All the equipments tested were measured for the electrical parameters and were tested in “on” and “off “modes. This method gives an idea of how much energy was consumed by the appliance. The data is then analysed to estimate the overall consumption assuming that the appliance runs for a specified period of time as stated for each equipment.

The analysis is them compared with new equipments to estimate the energy saving that would occur, and consequently, the decrease in the annual GHG emissions. The decrease in GHG emissions would hence result in carbon tax and money for the university to utilize in research or improvement of the facilities.

Results and Discussion

Seven labs in the Chemical and Biological engineering building were audited and power consumption data was gathered for each lab using a kill-a-watt meter rented from the U.BC library. This data was used to assess the following factors:

- Major energy consuming equipment commonly found in research labs such as: centrifuges, ovens, water baths, weighing scales and small instruments.
- Recommend green alternatives for the above mentioned equipment such as replacement or maintenance.
- Quantify the environmental benefit of new equipment compared to old equipment.
- Performing Life Cost Analysis (L.C.A) on new and old equipment.
- Economic analyses to determine feasibility of replaced equipment and determine long term savings.

The following seven labs were audited and their respective equipments were analysed:

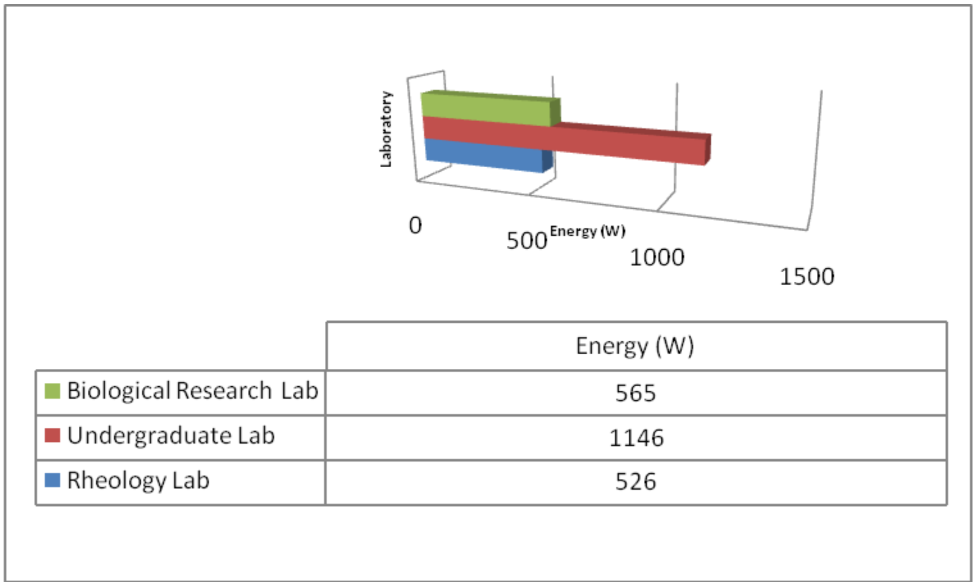
- Rheology Lab (Crusher, Hotplate, Vacuum Oven and Horizontal Mixer)
- Catalysis Research Lab (Furnace, Gas Chromatogram and Water Bath)
- Water Pollution Control lab (Calorimeter, Turbidometer and pH Ion Meter)
- Fuel Cell Research Lab (Biopotentiostat and Sonic Heater)
- Sensor Lab (Oven, MTI and Pressurized TGA)
- Undergraduate Lab (Digital Measuring Scale, Stirring Hot Plate, Water Bath and Centrifuge)
- Biological Research Lab (Stirring Hot Plate, Large Centrifuge and UV Transmitter)

Note: each lab contained computers; please refer to data sheets in appendix for specific numbers.

For each equipment, the kill-a-watt meter was used to record the frequency, current, voltage and power consumption. These values were recorded with the units both switched on and off. The recorded values were compared to each other to signify which equipments were major and minor power consumers; comparisons are given below for each equipment type:

Stirring Hotplate

Stirring hotplates are used in the laboratories for heating up chemicals while ensuring proper mixing. These can be energy intensive from the heating and stirring processes. The energy from the heating process will depend on the desired temperature gradient and heat transfer properties of the container. The energy from the stirring process will depend on the mass places on the surface of the hotplate. Three hotplates were analyzed during the audit and the results are illustrated below in Figure 2.



	Energy (W)
🟩 Biological Research Lab	565
🟥 Undergraduate Lab	1146
🟦 Rheology Lab	526

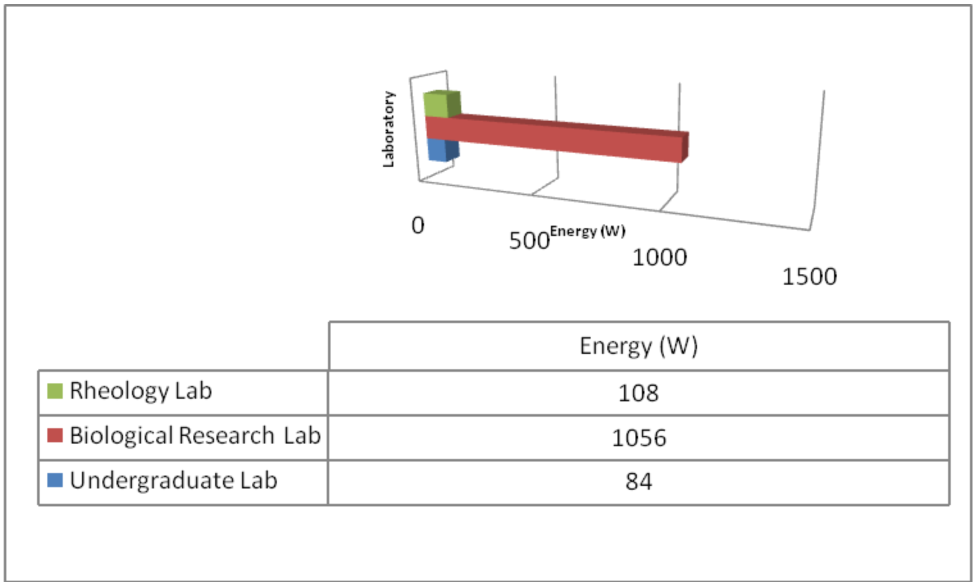
Figure 2 - Energy Consumption for Stirring Hotplate

As seen from Figure 2, the stirring hotplate from the undergraduate laboratory requires the greatest energy at 1146 W. This equipment was manufactured by Fischer Scientific and seems to have a lot of fouling due to the age; this could potentially have been reduced through preventive maintenance. The other two labs had similar requirements and hence it is suggested to purchase the Thermolyne Ciramec 2 model stirring hot plate.

The Thermolyne Ciramec 2 currently sells at $540 US. Assuming an operation of 45 days in a year (1080 hours), $116.64 is saved in a year. Hence, in approximately 5 years, the cost of the hot plate will be redeemed in addition to being sustainable. If the average lifespan of a hotplate was taken to be 15 years, a profit will be made starting in the 6th year and by the 15th year, a profit of $1161 will be made.

Centrifuge

Centrifuges are used in laboratories to separate solutions based on their densities; the larger the density gradient, the more effective of a separation will take place. The speed and throughput capacity of the centrifuge are the major factors for energy consumption. Three centrifuges were audited for energy consumption and the results are illustrated below in Figure 3.



	Energy (W)
🟩 Rheology Lab	108
🟥 Biological Research Lab	1056
🟦 Undergraduate Lab	84

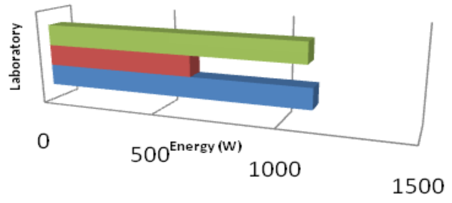
Figure 3 - Energy Consumption for Centrifuge

As seen from Figure 3, the centrifuge in the Biological research lab required the greatest energy. This is due to the size of the centrifuge since it had a throughput capacity several times greater than the ones audited in the other two labs. The large centrifuge is needed in the lab due to the research performed and cannot be replaced; however the centrifuge is a new product and hence would be complying with the latest technology available for saving energy. The smaller centrifuges however were observed to be older models and could potentially be replaced by newer and more energy efficient centrifuges. One such centrifuge would be Alfa Laval's Culturfuge 100 which is a lab scale centrifuge.

The power consumption of the centrifuge depends on the rotations per minute (RPM). The RPM can be adjusted based on the densities and separation factors required in the separation process; the higher the RPM, the more energy will be consumed. The above energy requirements found above in Figure 3 should be used carefully since it will vary considerably as mentioned earlier. In the audits that were performed, water was loaded and used to take the measurements.

Water Bath

Water baths are used in laboratory processes to heat water for jackets around chemical reactors so that isothermal conditions can be maintained. The input water is usually municipal water and the water is recycled back and forth between the reactor and pump. Most energy is consumed at the initial stages of heating because the water would be cold at first. The heat losses to the surroundings are dependent on insulation and are usually very minimal; hence once steady state has been reached, not much energy is required to maintain the temperature. In endothermic reactions, the heat of reaction is supplied to the reactor from the heater water. The energy consumption values from the audit are illustrated below in Figure 4.



	Energy (W)
🟩 Water Pollution Lab	1099
🟥 Catalysis Lab	637
🟦 Undergraduate Lab	1122

Figure 4 - Energy Consumption for Water Bath

As seen in the Figure above, the water baths in the undergraduate and water pollution labs consume the most energy; this could be due to poor insulation. Preventive maintenance should be performed on these water baths to ensure optimal efficiency and a longer lifespan.

Vacuum Oven

A vacuum oven is a type of furnace that heats materials to extremely high temperatures; is a form of heat treatment with low contamination. A vacuum is created inside the operating oven and results in an efficient heat transfer with the product through convection. The Vacuum oven (Sheldon Manufacturing, Model 1400 E) used in the Rheology Lab consumes 513 W of electricity; this is a typical value for a vacuum oven.

Gas Chromatogram

A gas chromatogram analyzes the species in a given liquid and is mostly used in organic chemistry for separating and analyzed compounds that can be vapourized without decomposition. In many industrial processes, GC is used to determine the purity of a particular substance. The gas chromatogram used in the Rheology Lab is manufactured by Mandel Scientific and costs approximately $275000.

The gas chromatogram in the laboratory consumes 122 W of electricity during operation. It has a short operating time and a high capital cost; hence is not viable to replace it. The GC used in the laboratory seems to be maintained well and can continue.

Horizontal Mixer

A horizontal mixer is used to mechanically mix substances placed in a cylinder, which rotates on two rotating disks. A horizontal mixer is a simple mechanical tool that is not a heavy energy consumer. A low energy consumption of 20 W and a low purchasing price deems that a replacement analysis is not viable.

Computers

Computers were found in each of the seven laboratories in vast numbers. Each laboratory had a different number of computers, depending on the usage; ranging from 1in the biological research lab to 9 in the undergraduate lab. Only one measurement was taken for the computer and this was found to be 93 W. The computers in all the labs were similar and modern; hence the only recommendation for saving energy would be to turn off unused computers.

All the other equipment can be found in Appendix A, under their respective laboratories. It was deemed unnecessary to do analyses on them due to their low power requirements and/or lack of data available.

The audits performed at the chemical engineering labs represent a sample population of laboratories across U.B.C. The energy consumption data can be extrapolated for other labs across the campus. Some major factors to consider would be equipment size, length and frequency of equipment operation. Some labs that would be similar to the chemical engineering labs would be labs found in the chemistry, physics and mining departments.

From the audits that were conducted, it was found that all the equipment consumed some form of energy when plugged in, regardless of being in operation or not. This suggests that while the equipments are not in operation, laboratory staff should ensure all equipment are unplugged. Light bulbs in all laboratories were found to be turned on regardless of staff being present in the rooms; hence it should be mandated that all lights be turned off when a room is not occupied. Ventilation systems were found to be always in operation; this is not required for all labs and hence should be turned off when no staffs are present.

If all the above recommendations were followed, a giant leap toward sustainability could be achieved and this in turn would results in one step to being closer to the 2010 carbon neutral requirements outlined by the provincial government. This in turn would result in U.B.C saving money in energy costs and becoming renowned for being a sustainable pioneer among universities.

Conclusion

In conclusion, it was found that the stirring hot plates in the undergraduate lab need to be replaced. The LCA analysis showed that the cost could be reclaimed within 5 years of purchasing and within 15 years, a profit of $1166 could be made. All the other equipment only needed preventative maintenance or was already adequate enough.

From the audits that were conducted, it was found that all the equipment consumed some form of energy when plugged in, regardless of being in operation or not. It was hence deemed that staff should ensure all equipment is unplugged when not in use and lights and ventilations should be turned off.

There are uncertainties that could not be taken into account in the results. These include: measuring only electrical energy and hence other sources were neglected, not all equipment were tested at maximum capacity and that most equipment were not given sufficient time to reach steady state. These could lead to errors such as energy requirements that are higher/lower than actual operation consumption rates.

When LCA was conducted, only economic considerations were taken into account. Environmental impacts such as waste emissions could not be accounted for; hence unforeseen costs could alter the profits calculated in the results.

It can be seen that to reach the goal of becoming carbon neutral by 2010, U.B.C still has some way to go. Every portion of energy saving will contribute to the goal being reached and it requires a unified effort by all individuals at U.B.C. If all the recommendations are followed, U.B.C will save money in energy costs and become a pioneer for sustainability programs in Canada.

Appendix A – Raw Data

Figure A1 Killawatt Meter (Source: Iona Lake Electricity Corp)

Note: Voltage is measured in Volts, Current in Amperes, Power in Watts and Frequency in Hertz in all tables.

Table A1 -Rheology Lab

		Voltage (V)	Current (Amp)	Power (W)	Frequency (Hz)
Crusher	Off	190.5	1.77	45	50
	Max Capacity	190.5	1.86	102	50
Stirring Hotplate	Off	191	1.77	44	50
	Max Capacity	189.5	3.33	570	51.8
Vacuum oven	Off	191	1.78	44	47.9
	Max Capacity	189.6	3.26	557	47.9
Horizontal mixer	Off	190	1.78	44	50.4
5 Computers	Max Capacity	190.5	1.78	64	50.5

Table A2 - Catalysis Lab

		Voltage (V)	Current (Amp)	Power (W)	Frequency (Hz)
Furnace	Off	192.2	1.76	44	49.1
Barstead Thermolyne	On	192.2	1.77	54	49.1
Gas Chromatogram	Off	1.92	1.77	45	51.8
Mandel Scientific (CHE 4701a)	On	192	1.88	166	50.4
Water bath	Off	192	1.77	43	51.8
VWR Scientific Products	On	192	3.88	680	51.8
3 Computers					

Table A3 - Water Pollution Control

		Voltage	Current	Power	Frequency
		(V)	(Amp)	(W)	(Hz)
Calorimeter	Off	190	1.76	45	47.9
LaMotte Smartz	On	190.3	1.76	47	46.7
Turbidimeter	Off	190.4	1.74	45	46.7
LaMotte (CHE 5342c)	On	190.5	1.76	47	46.7
pH Ion Meter	Off	187.8	1.76	46	46.7
Fishcher Scientific (accumat x125) **3 Computers**	On	188.1	1.77	51	49.1

Table A4 - Fuel Cell Lab

		Voltage	Current	Watt	Frequency
		(V)	(Amp)	(W)	(Hz)
Biopotentiostat	Off	189.6	1.76	45	46.7
AFC PP1 - Pine Instrument (CHE 57430)	On	190	1.77	55	46.7
Sonic Heator	Off	190.8	1.77	45	46.7
1510 Branson (CHE 54271)	On	190.8	1.77	50.4	46.7
3 Computers					

Table A5 - Sensor lab

MTI 50 K	Voltage	Current	Power	Frequency	KWH
OFF	191.9	1.77	43	51.8	0
ON	192.2	1.77	45	51.8	0
MTI machine with single pelletizer					
Pressureized TGA	Volt	Amp	Watt	Frequency	KWH
OFF	191.9	1.76	45	47.9	0
ON	189.6	6.05	283	49.3	0.01
Pressureized TGA , Thermax 500					
Oven	Volt	Amp	Watt	Frequency	KWH
OFF	193.2	1.76	45	51.8	0
ON	185.2	7.8	1441	50.4	0.01
Oven: Model 40 GC lab oven					

Table A6 - Undergraduate Lab

		Voltage	Current	Power	Frequency
Digital Measuring Scale	*Power Off*	189	1.77	47	51.8
CHE 8819	*Power On*	189	1.77	49	53.2
Cole-Parmer (Symmetry)					
Computer	*Power Off*	189.3	1.77	45	50.4
Thermocouple Experiment	*Power On*	189.3	1.96	138	53
Computer					
Stirring Hot Plate	*Power Off*	190	1.76	44	50.4
Fischer Scientific	*Power On*	190	6.48	1190	49.1
CHE 5286B					
Water Bath	*Power Off*	190	1.77	43	50
CHE 59139 VWR	*Power On*	184	6.38	1165	51.8
Centrifuge	*Power Off*	190	1.77	53	50.4
CHE 5548	*Power On*	190	1.96	137	50.4
Fishcer Scientific - Micro 14					
9 Computers					

Table A7 - Biology Research Lab

			Voltage	Current	Power	Frequency
Computer and Monitor	*Power Off*		189.3	1.77	45	50.4
	Power On		189.3	1.96	138	53
Stirring Hot Plate	*Power Off*		190.5	1.76	45	51.8
Thermolyne	*Power On*		190.7	1.77	610	51.8
Ciramic 2						
Big Centrifuge	*Power Off*		191	1.76	44	49.1
Fischer Scientific	*Power On*		190.5	60.4	1100	47.9
Centrofuge 5810R						
UV Transmitter	*Power Off*		191.5	1.77	44	49.1
Fischer Biotech	*Power On*		190.5	2.13	157	49.1
Electrophrosis System						
4 GE Fridges						
4 Computers						

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