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An Analysis of Resource Consumption in Cafeteria Dish-pits on Dalhousie Campuses

Heather Semotiuk, Jesse Sharp, Emily Stewart, Robin Tress, and Erin Wilson

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Abstract

The goal of this Greening the Campus research project was to assess the water and energy use in the dishwashing facilities at the four Dalhousie residence cafeterias. Understanding the amount of water and energy used in these areas is crucial to developing reduction strategies which will help to create a more sustainable university campus. Water and energy usage data for this project was collected by both direct measurement and non-probabilistic surveys. Each method of direct measurement was tailored to the different apparatus at each cafeteria. This data was then used to calculate fuel requirements and associated green house gas emission per cafeteria. Due to time restrictions and lack of information, the green house gas calculations were deemed invalid and should be disregarded. It was discovered that Howe Hall cafeteria consumes the most amount of water and uses the most amount of energy. In a week the four cafeterias together consume 152, 965L of water and use 10, 444 kWh of energy. Recommendations to reduce water and energy use were made based upon water and energy use data collected. These reduction methods included behavioural changes as well as product upgrades and infrastructure retrofits.

Table of Contents

1. Introduction

1.1 Background Information

"The community neither begins nor ends at the gates of the university; it seeps through the gates and into the doors of its academic halls" (Shannon and Wolff, 1952). In a global community moving towards environmental sustainability, universities have a responsibility to be leaders in green technology and social behavioural change. In the past two decades, universities across North America have implemented various energy, water, and fossil fuel reduction strategies such as carpooling, energy-efficient buildings, and local food programs (Keniry, 1995; Callender, 2009; Smulders, 2008). More recently, large amounts of attention have been paid towards food production and preparation for campus cafeterias. Thousands of students depend on residence cafeterias for their daily meals, and so these meal halls have become huge centres for energy and water use. About 80% of water used in kitchens is dedicated to dishwashing, and two thirds of this energy used in dishwashing is allocated to heating the water (campuserc.org, 2007). With such enormous allocations of resources used just to wash up after a meal, the 'dish-pit' was an appropriate target for reducing resource consumption at Dalhousie.

Dalhousie University is contributing to the world-wide campus movement towards sustainability. It has signed the Halifax Declaration, the Talloires Declaration and the UNEP International Declaration on Cleaner Production; three international declarations relating to sustainability and the environment (Office of Sustainability, 2009a). Part of Dalhousie's Sustainability Policy is to decrease resource use such as energy and water (Office of Sustainability, 2009b). Minimizing the amount of water and energy used will not only make Dalhousie greener but will also save the university money and set an example for other universities and the surrounding community. The University has already taken steps to reduce energy and water use in the campus cafeterias by removing the use of trays in 2008. This simple change saves the University about 3000L of water per day, and about $13 000 in electricity costs per year (www.greenreportcard.org, 2010).

1.2 *Research Problem*

In Dalhousie cafeterias, the dish-pit area consumes the most water of any other area in the kitchen. To heat this water to the industry standard of 82°C (Government of Canada, 2000) energy is consumed as well. Because this area uses a large quantity of resources, the potential for water and energy savings is also great. Understanding the total amount of water and energy use as well as how it is used is a first step in being able to find solutions for resource reduction. The information collected in this research will provide a base for assessing more sustainable practice possibilities in the dish-pits and striving towards Dalhousie's goal of a greener campus.

The purpose of this research was is to assess the water and energy use of the dish pits (the dishwasher, sprayers, and sanitation sinks) at the four Dalhousie residence cafeterias (Howe, Risley, Sherriff and O'Brien Halls). Potential methods of water and energy conservation can only be explored and implemented once the use and allocation of these resources is fully understood.

1.3 *Importance to Campus Sustainability*

This Greening the Campus project addresses the need to reduce water and energy use. This assessment is a combination of methods from related projects, and provides standardized methods of data collection for several types of dish-washing equipment. Due to the variations between each of Dalhousie's four cafeterias, the findings of this study will carry over and apply to many cafeterias on other campuses. These methods can be applied to any cafeteria or kitchen with similar apparatuses, and can therefore be thought of as a significant contribution to the Greening the Campus movement.

2. Research Methods

The following methods will be used in this descriptive investigation:

- *Walkthrough* of one of the cafeteria kitchens
- *Informal interviews* with kitchen staff and management using non-probabilistic, purposeful sampling
- *Observation* of the dish pit
- *Measurement* and *Calculation* of water flow rate
- *Calculation* of energy use
- *Online research* to determine technical specifications of dishwasher from manufacturer

All of these methods were carried out at the four cafeterias on campus: Risley Hall, Howe Hall, Shirreff Hall, and O'Brien Hall. Data was compared and contrasted across the cafeterias, the results of which directed the analysis for potential water and energy reduction solutions.

2.1 *Walkthrough*

The walkthrough of the kitchen was conducted to identify the main appliances drawing the most energy and water. All the researchers involved in this project took a guided tour of the Howe Hall cafeteria, which serves the largest population of students on campus. Robin Tress also took a tour of O'Brien Hall. The kitchen manager and one of the head chefs pointed out appliances and kitchen functions that used the most water and energy. The dish-pit stood out as the greatest consumer of water and energy from the perspective of the kitchen staff and management. This statement was later supported by the staff at the other cafeterias.

2.2 *Informal Interviews*

Informal interviews with the kitchen staff and management were conducted. The goals of the interviews were to determine typical, consistent practices within the dish-pits. These interviews, in combination with direct observation, were used for triangulation such as when the tap is running and when it is not in use.

2.3 *Observation*

Observations of the dish pit helped to determine when water is used; these observations were triangulated by the interviews. The observations looked at:

- If the tap on the sinks is running and used
- If the tap is running and not in use
- If a sprayer or other appliance is in use
- How many times the dishwasher is run over a period of time

When temperature measurements were taken, the above factors were checked in all four residence cafeterias if applicable. These observations were used to triangulate the claims made during the informal interviews. The number of times the dishwasher was run in a day was counted by the cafeteria staff. These counts were conducted on one weekday and one weekend in each cafeteria, as the kitchen staff noted a difference in cafeteria use by students on weekends. Due to time constraints for the staff, and the amount of work they have, they could only conduct the counts on one weekday and one weekend; ideally, these counts would have taken place over several days, and an average would have been created to use in subsequent calculations. The external verification of the dishwasher counts was another limitation to the counts, as there was no way for the researchers to check the validity of these values. Having a researcher present in the cafeteria during all working hours was impossible due to the time-consuming nature of this type of observation and the limited space within the cafeteria.

2.4 *Measurement and Calculation of Water Use*

Three of the four cafeterias (Shirreff, Risley and Howe) had sinks. The sink station typically consisted of three basins, one for washing, rinsing, and sanitizing, whereas Risley only had a wash sink and a rinse sink. The sinks were measured with a measuring tape to determine the volume of water required to fill each. This volume, multiplied by the number of times the sinks were filled in a day, resulted in the water volume used by the sinks per day. In Howe Hall, the sanitizing sink was omitted from calculations due to unpredictable variability in volume of water used. This exclusion did not affect energy calculations because the water in the sanitizing sink was not heated. The tap in the rinsing sink in Howe Hall is left on continuously.

The flow rates of the taps were estimated using the procedure adapted from Adams et al. (2009). A bucket was placed under the tap and the water was run for a period of ten seconds. After this time has elapsed, the volume of water in the bucket was measured using a measuring cup in millilitres (mL). This measurement was repeated and calculated for three trials with the average taken to calculate a 'L/minute' flow rate (Adams et al 2009). The same procedure was used to determine the flow rate of the sprayers in every cafeteria. For the pipes in Shirreff, the measuring cup was held directly under one nozzle of the pipe for ten seconds and then multiplied by 17, as there were 17 nozzles in total. For both the sprayers and the pipe, the calculated L/minute flow rate was multiplied by the hours used, resulting with a water usage total. Exact outline of calculations can be found in Appendix A.

2.5 *Calculation of Energy Use*

An energy use calculation took place. Measurements of the temperature of the water from the tap, sprayer and pipe, if applicable, were obtained three times each day for three days using a mercury thermometer. The three temperature measurements on the same day with the multiple replications increased the validity and reliability of the measurements through similar measurements over multiple days of recording. The minimum temperature of water exiting the tap was measured using the abovementioned procedure. The minimum water temperature was based on the assumption that the temperature of cold water exiting the taps is equal to the temperature of the water entering the water heaters. The differences between the minimum and maximum temperatures of water was used to calculate the energy required to heat the water (see appendix A). It has been noted that ambient water temperature may vary with the seasons; however, based on the limitations of this project, data collection will be restricted to the ambient temperature of water within a short one-to-two week timeframe in March. The difference between the incoming and heated temperature measurements, along with the heat capacity of water and the water amounts (previously calculated from the water flow rate) will allow us to determine the amount of energy use to heat the water using the following equations:

$$q=mc\Delta T$$

where ΔT is the difference in temperature between the incoming water and the heated water, m is the mass of water that is heater, c is the specific heat capacity of water, and q is the energy used in heating in kilojoules (kJ). The energy values found were then converted to kilowatt hours (kWh). Further equations can be found in Appendix A outlining the exact methods of all calculations.

2.6 *Manufacturer Research*

The specifics of energy and water consumption per load of the dishwater were gathered from the Hobart Corporation, the manufacturer of Dalhousie's commercial dishwashers. Research online was undertaken to determine the manufacturer specifications about the energy use of the appliances. A manufacturer spokesperson, Bob McGillivary, was called for model specifications, which allowed the water use and thus energy use to be calculated.

2.7 *Fuel Use and* CO_2 *Production*

The amount of fuel required to power each cafeteria's dish-pit was calculated. This was completed using the total kWh of energy per cafeteria, the energy density of Bunker C (the fuel used in Risley, Shirreff and Howe Halls) and the energy density of oil (the fuel used in O'Brien Hall). The CO_2 emissions associated with the combustion of these fuels was also calculated using the kg CO_2 per kWh produced by the combustion of these fuels. These calculations are demonstrated in detail in Appendix A.

2.8 *Feasibility of Possible Alternatives*

Potential solutions are presented based on our results. These include: social/behavioural changes for cafeteria staff and students, removal of unnecessary equipment, and/or upgrading appliances.

2.9 *Limitations and Delimitations*

The research included a time limit of about three weeks. This made it difficult to analyse everything, and as such, one delimitation was to focus solely on the dish-pits. Another limitation arose as to the variability of our measurements. The water use can change enormously depending on the number of students, the type of meal served, and especially for Howe, the amount of catering done on a certain day. Cafeteria workers also exert significant influence if the sinks are emptied and refilled (~ 500L at Howe). Interviewers asked for the total hours used on average in a day, but variation in the amount of times a sink is filled can have a huge effect. Another limitation is the inability to secondarily verify the dishwasher counts.

Delimitations were established to focus in on energy use in heating. Calculations are low estimates as we only accounted for the energy use required to heat up the water, not to keep it at that temperature. This would have required much more analysis and measurement that what the research time would allow, so the focus was narrowed to the initial heating.

3. Results

Dalhousie University has four cafeterias intended to serve students in residence and on campus. These four cafeterias are located in Howe Hall, Shirreff Hall, Risley Hall and Obrien Hall. Each has a similar method of dishwashing, however none are identical.

3.1 *Risley Hall Cafeteria*

Risley Hall is equipped with a Hobart C44A dishwasher, two sinks for washing large pots and pans, and a sprayer. The dishwasher washes one tray of dishes at a time, using 3.8L per wash cycle and 1.8 L per rinse cycle. The average wash cycle temperature in the dishwasher was 70.22 ºC and the rinse cycle was 80 ºC. The sprayer use was highly variable, but the dish-pit staff estimated that it was used for 20 seconds per load of dishes. The average flow rate of the sprayer in Risley Hall was 4L/minute. The average incoming temperature (referred to as the minimum water temperature) was 5.5 ºC. The total energy used to heat wash water in Risley Hall was 2667 kWh per week, and the total volume of water was 36430 L.

Table 1.1: Number of students who ate in the cafeteria and number of loads of dishes washed in Risley Hall Cafeteria on one week day (Monday-Friday) and one weekend day (Saturday-Sunday).

	# Students	**# Loads washed**	**Loads per student**
Weekday	1100	621	0.56
Weekend	724	460	0.63

Table 1.2: Measured and average dishwasher wash-cycle water temperatures from Risley Hall Cafeteria in degrees Celsius.

Trial	Day 1	Day 2	Day 3	
1	72	67	71	
2	73	67	72	**Average**
3	72	66	72	**70.22**

Table 1.3: Measured and average dishwasher rinse-cycle water temperatures from Risley Hall Cafeteria in degrees Celsius.

Trial	Day 1	Day 2	Day 3	
1	83	75	82	
2	81	79	81	**Average**
3	80	78	81	**80.00**

Table 1.4: Measured and average spray water temperature from Risley Hall Cafeteria in degrees Celsius.

Trial	Day 1	Day 2	Day 3	
1	50	47	50	
2	55	47	53	**Average**
3	52	49	51	**50.44**

Table 1.5: Flow rate of sprayer in Risley Hall Cafeteria in litres per minute (L/min).

Trial 1	Trial 2	Trial 3	Average L/min
4.00	4.10	4.20	4.00

Table 1.6: Total volume of water used by sprayers in Risley Hall Cafeteria per week, and the energy to heat that water.

Number of Loads	Spray time per load (seconds)	Flow rate (L/min)	Total water use per week (L)	Total Energy use per week (kWh)
1081	20	4	1441.33	84.54

Table 1.7: Dimensions and volume of sinks at Risley Hall Cafeteria.

	Sink 1	Sink 2
Width (cm)	60.5	60.5
Depth (cm)	56.0	56.0
Length (cm)	28.5	28.5
Volume (L)	96.56	96.56
Times filled per weekday	4	3
Times filled per weekend	2	2
Total Volume per week (L)	2317.39	1834.60
Energy Used to heat water in sinks (kWh)	234.71	

Table 1.8: Measured and average maximum and minimum water temperatures of sinks at Risley Hall Cafeteria in degrees Celsius.

	Sink1 Maximum	Sink 2 Maximum	Sink 1 Minimum	Sink 2 Minimum
Trial 1	56.0	50.0	5.0	5.5
Trial 2	60.0	50.0	5.5	6.5
Trial 3	59.0	51.0	5.0	5.5
Average	50.4		5.5	

Table 1.9: Dishwasher C44A water usage per day in Risley Hall, modeled using cafeteria usage from January 11-17 and dishwasher loads per student (values as seen in Table 1).

Number of students	Number of loads	Wash water (L)	Rinse Water (L)	Energy to heat wash water	Energy to heat rinse water
1440	812.88	3088.94	1463.18	232.48	126.76
1353	763.77	2902.32	1374.78	218.43	119.10
1298	732.72	2784.34	1318.90	209.55	114.26
1204	679.66	2582.70	1223.38	194.38	105.99
1090	615.31	2338.16	1107.55	175.97	95.95
651	413.65	1571.85	744.56	118.30	64.50
685	435.25	1653.95	783.45	124.48	67.87
Totals	**4453**	**16922.26**	**8015.81**	**1273.59**	**694.44**

Table 1.10: Dishwasher C44A water usage per day in Risley Hall, modeled using cafeteria usage from February 8-14 and dishwasher loads per student (values as seen in Table 1).

Number of Students	Number of Loads	Wash Water (L)	Rinse water (L)	Energy to heat wash water (kWh)	Energy to heat rinse water (kWh)
1282	723.69	2750.02	1302.64	238.24	112.85
1186	669.50	2544.09	1205.09	220.40	104.40
1401	790.86	3005.29	1423.56	260.36	123.33
1257	709.58	2696.39	1277.24	233.60	110.65
1202	678.53	2578.41	1221.35	223.38	105.81
753	478.46	1818.13	861.22	157.51	74.61
692	439.70	1670.85	791.45	144.75	68.57
Totals	**4371**	**24479.74**		**1478.25**	**700.22**

Table 1.11: Dishwasher C44A water usage per day in Risley Hall Cafeteria model, created using cafeteria usage data from March 8-14 and dishwasher loads per student (values as seen in Table 1).

Number of Students	Number of Loads	Wash Water (L)	Rinse water (L)	Energy to heat wash water (kWh)	Energy to heat rinse water (kWh)
1308	738.37	2805.79	1329.06	211.17	115.14
1268	715.79	2719.99	1288.41	204.71	111.62
1260	711.27	2702.83	1280.29	203.42	110.92
1221	689.25	2619.17	1240.66	197.12	107.48
1156	652.56	2479.74	1174.61	186.63	101.76
624	396.49	1506.66	713.68	113.39	61.83
736	467.65	1777.09	841.78	133.75	72.93
Totals	**4371**	**16611.25**	**7868.49**	**1250.18**	**681.68**

3.2 *O'Brien Hall Cafeteria*

O'Brien Hall has the simplest dish-pit system, including only a Hobart CRS66A dishwasher and a spray hose used to rinse dishes prior to washing them. The dishwasher washes one tray of dishes at a time, using 3.6L of water per wash cycle and 1.4 L per rinse cycle. The average water temperatures for the dishwasher were 72.54ºC for the wash cycle and 82.33 ºC for the rinse cycle. The sprayer use was highly variable, however dish-pit staff estimated that the sprayer was used for 20 seconds per load of dishes. The average flow rate of the sprayer in Obrien Hall was 2.2 L/minute. The average incoming temperature (referred to as the minimum water temperature) was 5.5 ºC. The total energy use to heat wash water in Obrien Hall was 1344 kWh/week, and the total volume of water was 16307 L. Water in O'Brien Hall is heated by the combustion of oil. To supply O`Brien`s cafeteria with enough energy to heat its water, 119L of oil must be consumed each week, creating annual CO_2 emissions of 9784kg. The CRS66A model dishwasher is scheduled to be replaced by a CL44e new dishwasher in the 2010/2011 school year.

Table 2.1: Number of students who ate in the cafeteria and number of loads of dishes washed in O'Brien Hall Cafeteria on one week day (Monday-Friday) and one weekend day (Saturday-Sunday).

	# Students	# Loads washed	Loads per student
Weekday	345	417	1.21
Weekend	321	566	1.76

Table 2.2: Measured and average dishwasher wash-cycle water temperatures from O'Brien Hall Cafeteria in degrees Celsius.

Trial	Day 1	Day 2	Day 3	
1	71	74	74	
2	72	72	73	**Average**
3	72	73	70	**72.54**

Table 2.3: Measured and average dishwasher rinse-cycle water temperatures from O'Brien Hall Cafeteria in degrees Celsius.

Trial	Day 1	Day 2	Day 3	
1	82	82	82	
2	83	83	83	**Average**
3	82	82	82	**82.33**

Table 2.4: Measured and average spray water temperature from O'Brien Hall Cafeteria in degrees Celsius.

Trial	Day 1	Day 2	Day 3	
1	41	39	41	
2	43	41	43	**Average**
3	41	41	41	**41.18**

Table 2.5: Flow rate of sprayer in O'Brien Hall Cafeteria in litres per minute (L/min).

Trial 1	Trial 2	Trial 3	Average L/min
2.1	2.2	2.1	2.2

Table 2.6: Total volume of water used by sprayers in O'Brien Hall Cafeteria per week, and the energy to heat that water.

Number of Loads	Spray time per load (seconds)	Flow rate (L/min)	Total water use per week (L)	Total Energy use per week (kWh)
2651	20	2.1	1855.7	78.1

Table 2.7: Dishwasher CRS66A water usage per day at O'Brien Hall Cafeteria, modeled using cafeteria usage from January 11-17 and dishwasher loads per student (values as seen in Table 1).

Number of students	Number of loads	Wash water (L)	Rinse Water (L)	Energy to heat wash water	Energy to heat rinse water
386	466.55	1679.61	653.18	150.06	50.92
385	465.34	1675.26	651.49	149.67	50.79
368	444.80	1601.28	622.72	143.06	48.55
376	454.47	1636.10	636.26	146.17	49.60
362	437.54	1575.17	612.57	140.73	47.76
306	269.76	971.17	377.68	86.77	29.44
371	327.07	1177.46	457.90	105.20	35.70
Totals	2865.57	10316.06	4011.80	921.67	312.76

Table 2.8: Dishwasher CRS66A water usage per day at O'Brien Hall Cafeteria, modeled using cafeteria usage from February 8-14 and dishwasher loads per student (values as seen in Table 1).

Number of Students	Number of Loads	Wash Water (L)	Rinse water (L)	Energy to heat wash water (kWh)	Energy to heat rinse water (kWh)
351	424.25	1527.31	593.96	136.46	46.30
364	439.97	1583.88	615.95	141.51	48.02
352	425.46	1531.66	595.65	136.84	46.44
387	467.77	1683.96	654.87	150.45	51.05
308	372.28	1340.21	521.19	119.74	40.63
345	304.15	1094.95	425.81	97.83	33.20
352	310.32	1117.16	434.45	99.81	33.87
Totals	2744.20	9879.14	3841.89	882.64	299.51

Table 2.9: Dishwasher CRS66A water usage per day in O'Brien Hall Cafeteria model, created using cafeteria usage data from March 8-14 and dishwasher loads per student (values as seen in Table 1).

Number of Students	Number of Loads	Wash Water (L)	Rinse water (L)	Energy to heat wash water (kWh)	Energy to heat rinse water (kWh)
367	443.59	1596.93	621.03	142.6755	48.41479
376	454.47	1636.10	636.26	146.1743	49.60208
360	435.13	1566.48	609.18	139.9542	47.49135
383	462.93	1666.56	648.10	148.8957	50.52552
350	423.05	1522.96	592.26	136.0665	46.17215
340	299.74	1079.08	419.64	96.40849	32.71478
361	318.26	1145.73	445.56	102.3631	34.7354
Totals	2837.17	10213.83	3972.04	912.5379	309.6561

Table 2.10: Projected dishwasher (CL44e) water usage per day at O'Brien Hall Cafeteria, created based on cafeteria usage from January 11-17 and dishwasher loads per student (values as seen in Table 1).

Number of Students	Number of Loads	Wash Water (L)	Rinse water (L)	Energy to heat wash water (kWh)	Energy to heat rinse water (kWh)
351	424.25	1527.31	593.96	136.46	46.30
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352	310.32	1117.16	434.45	99.81	33.87
Totals	2744.20	9879.14	3841.89	882.64	299.51

Table 2.11: Projected dishwasher (CL44e) water usage per day at O'Brien Hall Cafeteria, created based on cafeteria usage from February 8-14and dishwasher loads per student (values as seen in Table 1).

Number of Students	Number of Loads	Wash Water (L)	Rinse water (L)	Energy to heat wash water (kWh)	Energy to heat rinse water (kWh)
351	424.25	1527.31	593.96	136.46	46.30
364	439.97	1583.88	615.95	141.51	48.02
352	425.46	1531.66	595.65	136.84	46.44
387	467.77	1683.96	654.87	150.45	51.05
308	372.28	1340.21	521.19	119.74	40.63
345	304.15	1094.95	425.81	97.83	33.20
352	310.32	1117.16	434.45	99.81	33.87
Totals	2744.20	9879.14	3841.89	882.64	299.51

Table 2.12: Projected dishwasher (CL44e) water usage per day at O'Brien Hall Cafeteria, created based on cafeteria usage from March 8-14 and dishwasher loads per student (values as seen in Table 1).

Number of Students	Number of Loads	Wash Water (L)	Rinse water (L)	Energy to heat wash water (kWh)	Energy to heat rinse water (kWh)
351	424.25	1527.31	593.96	136.46	46.30
364	439.97	1583.88	615.95	141.51	48.02
352	425.46	1531.66	595.65	136.84	46.44
387	467.77	1683.96	654.87	150.45	51.05
308	372.28	1340.21	521.19	119.74	40.63
345	304.15	1094.95	425.81	97.83	33.20
352	310.32	1117.16	434.45	99.81	33.87
Totals	2744.20	9879.14	3841.89	882.64	299.51

3.3 *Shirreff Hall Cafeteria*

Shirreff Hall uses a Hobart CRS66A dishwasher, a sprayer to rinse dishes before washing, three sinks used for washing large pots and pans, and a pipe- sprayer system to rinse dirty dishes as students bring them in. The dishwasher washes one tray of dishes at a time, using 3.6L per wash cycle and 1.4 L per rinse cycle. The average water temperatures for the dishwasher were 69.20ºC for the wash cycle and 83.10 ºC for the rinse cycle. The sprayer use was highly variable, but the dish-pit staff estimated that it was used for 20 seconds per load of dishes. The average flow rate of the sprayer in Shirreff Hall was 5 L/minute. The pipe-sprayer system has 17 nozzles that have a total flow rate of 4.76L/minute, using 371 L of water per week. The average incoming temperature was 6ºC. The total energy used to heat wash water in Shirreff Hall was 1809 kWh per week, and the total volume of water was 28884 L.

Table 3.1: Number of students who ate in the cafeteria and number of loads of dishes washed in Shirreff Hall Cafeteria on one week day (Monday-Friday) and one weekend day (Saturday-Sunday).

	# Students	# Loads washed	Loads per student
Weekday	1292	438	0.34
Weekend	736	389	0.53

Table 3.2: Measured and average dishwasher wash-cycle water temperatures from Shirreff Hall Cafeteria in degrees Celsius.

Trial	Day 1	Day 2	Day 3	
1	71	70	70	
2	68	69	69	**Average**
3	69	68	69	**69.20**

Table 3.3: Measured and average dishwasher rinse-cycle water temperatures from Shirreff Hall Cafeteria in degrees Celsius.

Trial	Day 1	Day 2	Day 3	
1	84	84	83	
2	84	82	83	**Average**
3	83	82	83	**83.10**

Table 3.4: Measured and average sink water temperature from Shirreff Hall Cafeteria in degrees Celsius.

Trial	Sink 1 Maximum	Sink 1 Minimum	Sink 2 Maximum	Sink 2 Minimum	Sink 3 Maximum	Sink 3 Minimum
1	46	6	46	6	46	6
2	45	6	45	6	44	6
3	41	6	42	6	41	6

Table 3.5: Flow rate of pipe-sprayer in Shirreff Hall Cafeteria in litres per minute (L/min).

Trial 1	Trial 2	Trial 3	Average L/min
6.71	6.93	1.42	**5.00**

Table 3.6: Measured and average maximum and minimum water temperatures from Shirreff Hall Cafeteria in degrees Celsius.

Trial	Day 1	Day 2	Day 3	
1	46	45	41	
2	46	45	42	**Average**
3	46	44	41	**44.00**

Table 3.7: Flow rate of pipe-sprayer in Shirreff Hall Cafeteria in litres per minute (L/min).

	Trial 1	Trial 2	Trial 3	Average L/min
One nozzle of sprayer	0.28	0.28	0.28	**0.28**
All 17 nozzles	4.76	4.76	4.76	**4.76**

Table 3.8: Total volume of water used by pipe-sprayer in Shirreff Hall Cafeteria per week, and the energy to heat that water.

Spray time per week (min)	Flow rate (L/min)	Total water use per week (L)	Total Energy use per week (kWh)
2340	4.76	11138.40	379.90

Table 3.9: Dimensions and volume of sinks at Shirreff Hall Cafeteria.

	Sink 1	Sink 2	Sink 3
Width (cm)	75.3	76.0	75.5
Depth (cm)	21.5	21.5	21.5
Length (cm)	61.5	61.5	61.5
Volume (L)	99.57	98.95	101.32
Times filled per weekday	4	4	4
Times filled per weekend	2	2	2
Total Volume per week (L)	2389.57	2374.85	2431.70
Energy Used to heat water in sinks (kWh)	105.59	104.94	107.45

Table 3.10: Measured and average sink water temperature of pipe conveyor at Shirreff Hall Cafeteria in degrees Celsius.

Trial	Day 1	Day 2	Day 3	
1	54	42	6	
2	60	42	6	**Average**
3	60	42	6	**35.33**

Table 3.11: Dishwasher CRS66Awater usage per day at Shirreff Hall, modeled using cafeteria usage from January 11-17 and dishwasher loads per student (values as seen in Table 1).

Number of students	Number of loads	Wash water (L)	Rinse Water (L)	Energy to heat wash water	Energy to heat rinse water
1344	455.62	1640.22	637.86	120.5523	57.18355
1285	435.62	1568.21	609.86	115.2602	54.67326
1332	451.55	1625.57	632.17	119.4759	56.67298
1321	447.82	1612.15	626.95	118.4893	56.20496
1182	400.70	1442.51	560.98	106.0214	50.29089
783	413.82	1489.74	579.34	109.4922	51.93724
749	395.85	1425.05	554.19	104.7378	49.68199
Totals	**3001**	**10803**	**4201**	**794**	**377**

Table 3.12: Dishwasher CRS66A water usage per day at Shirreff Hall, modeled using cafeteria usage from February 8-14 and dishwasher loads per student (values as seen in Table 1).

Number of Students	Number of Loads	Wash Water (L)	Rinse water (L)	Energy to heat wash water (kWh)	Energy to heat rinse water (kWh)
1322	448.16	1613.37	627.42	118.58	56.25
1324	448.84	1615.81	628.37	118.76	56.33
1297	439.68	1582.86	615.56	116.34	55.18
1315	445.79	1604.83	624.10	117.95	55.95
1197	405.78	1460.82	568.10	107.37	50.93
752	397.43	1430.76	556.40	105.16	49.88
760	401.66	1445.98	562.32	106.28	50.41
Totals	**2987**	**10754**	**4182**	**790**	**375**

Table 3.13: Dishwasher CRSS66A water usage per day in Shirreff Hall Cafeteria model, created using cafeteria usage data from March 8-14 and dishwasher loads per student (values as seen in Table 1).

Number of Students	Number of Loads	Wash Water (L)	Rinse water (L)	Energy to heat wash water (kWh)	Energy to heat rinse water (kWh)
1347	456.63	1643.88	639.29	120.82	57.31
1267	429.51	1546.25	601.32	113.65	53.91
1295	439.01	1580.42	614.61	116.16	55.10
1242	421.04	1515.74	589.45	111.40	52.84
1085	367.82	1324.13	514.94	97.32	46.16
673	355.68	1280.45	497.95	94.11	44.64
749	395.85	1425.05	554.19	104.74	49.68
Totals	**2866**	**10316**	**4012**	**758**	**360**

3.4 *Howe Hall Cafeteria*

Howe Hall is equipped with a Hobart CRS66A dishwasher, three sinks for washing pots and pans, and a sprayer used to rinse dishes before putting them in the dishwasher. . The dishwasher washes one tray of dishes at a time, using 3.6L per wash cycle and 1.4 L per rinse cycle. The average water temperatures for the dishwasher were 68.70ºC for the wash cycle and 82.59 ºC for the rinse cycle. The average temperature of water in sinks was 50.40ºC. The sprayer use was highly variable, but the dish-pit staff estimated that it was used for 20 seconds per load of dishes. The average flow rate of the sprayer in Howe Hall was 5 L/minute. The average incoming temperature was 6ºC. The total energy used to heat wash water in Howe Hall was 4242 kWh per week, and the total volume of water was 60960 L. The CRS66A model dishwasher is scheduled to be replaced by a CL44e new dishwasher in the 2010/2011 school year.

Most of Studley Campus gets its energy supply from Dalhousie's own bunker-C steam generator. The energy requirements of the dish-pits of Shirreff, Howe and Risley Halls as shown by this study would require 1175 kg of bunker-C to be burned each week. The combustion of this amount of bunker-C would create annual emissions of 105201 kg of CO_2.

Table 4.1: Number of students who ate in the cafeteria and number of loads of dishes washed in Howe Hall Cafeteria on one week day (Monday-Friday) and one weekend day (Saturday-Sunday).

	# Students	# Loads washed	Loads per student
Weekday	1384	479	0.35
Weekend	1012	424	0.42

Table 4.2: Measured and average dishwasher wash-cycle water temperatures from Howe Hall Cafeteria in degrees Celsius.

Trial	Day 1	Day 2	Day 3	
1	68	70	68	
2	70	69	68	**Average**
3	68	67	70	**68.70**

Table 4.3: Measured and average dishwasher rinse-cycle water temperatures from Howe Hall Cafeteria in degrees Celsius.

Trial	Day 1	Day 2	Day 3	
1	83	82	82	
2	82	83	83	**Average**
3	83	83	83	**82.59**

Table 4.4: Dimensions and volume of sinks at Howe Hall Cafeteria.

	Sink 1	Sink 2	Sink 3*
Width (cm)	61	61	61
Depth (cm)	61	61	61
Length (cm)	45	45	45
Volume (L)	502.335	502.335	502.335
Times filled per weekday	24	12	-
Times filled per weekend	24	12	-
Total Volume per week (L)	28130.75	14065.38	-
Energy Used to heat water in sinks (kWh)	1922.77	961.38	0

*Sink 3 was omitted from calculations due to unpredictable variability in volume of water used. This does not affect energy calculations because the water was not heated

Table 4.5: Measured and average maximum and minimum water temperatures of sinks at Howe Hall Cafeteria in degrees Celsius.

	Sink1 Maximum	Sink 2 Maximum	Sink 3 Maximum	Sink 1 Minimum	Sink 2 Minimum	Sink 3 Minimum
Trial 1	64	64.5	65	5.5	5.5	6
Trial 2	64.5	63	63.5	6	5.5	5.5
Trial 3	64	65	65	5	5.5	5
Average		50.4			5.5	

Table 4.6: Dishwasher CRS66A water usage per day at Howe Hall Cafeteria, modeled using cafeteria usage from January 11-17 and dishwasher loads per student (values as seen in Table 1).

Number of students	Number of loads	Wash water (L)	Rinse Water (L)	Energy to heat wash water	Energy to heat rinse water
1715	593.56	1020.92	397.68	75.15283	35.65185
1848	639.59	1100.09	428.52	80.98101	38.41669
1509	522.26	898.29	349.92	66.12573	31.36947
1474	510.15	877.46	341.80	64.592	30.64188
1621	561.02	964.96	375.89	71.03367	33.69776
989	342.29	588.74	229.33	43.33886	20.55958
854	295.57	508.38	198.03	37.42304	17.75317
Totals	3464.44	5958.84	2321.18	75.15283	35.65185

Table 4.7: Dishwasher CRS66A water usage per day at Howe Hall Cafeteria, modeled using cafeteria usage from February 8-14 and dishwasher loads per student (values as seen in Table 1).

Number of Students	Number of Loads	Wash Water (L)	Rinse water (L)	Energy to heat wash water (kWh)	Energy to heat rinse water (kWh)
1939	671.08	1154.265	449.6263	84.96871	40.30842
1630	564.14	970.3204	377.9736	71.42806	33.88485
1539	532.64	916.1491	356.872	67.44036	31.99312
1758	608.44	1046.517	407.655	77.03713	36.54575
1101	381.05	655.4127	255.3061	48.2468	22.88787
1112	465.90	801.3426	312.1509	58.98912	27.98393
973	407.66	701.1748	273.132	51.61548	24.48594
Totals	3630.92	6245.181	2432.716	459.7257	218.0899

Table 4.8: Dishwasher CRS66A water usage per day in Howe Hall Cafeteria model, created using cafeteria usage data from March 8-14 and dishwasher loads per student (values as seen in Table 1).

Number of Students	Number of Loads	Wash Water (L)	Rinse water (L)	Energy to heat wash water (kWh)	Energy to heat rinse water (kWh)
1735	600.48	1032.83	402.32	76.03	36.07
1513	523.65	900.67	350.84	66.30	31.45
1566	541.99	932.22	363.13	68.62	32.55
1499	518.80	892.34	347.60	65.69	31.16
1382	478.31	822.69	320.47	60.56	28.73
824	345.23	593.80	231.31	43.71	20.74
811	339.79	584.43	227.66	43.02	20.41
Totals	3348.24	5758.98	2243.32	423.93	201.11

Table 4.9: Projected dishwasher (CL44e) water usage per day in Howe Hall Cafeteria, based on cafeteria usage data from January 11-17 and dishwasher loads per student (values as seen in Table 1).

Number of Students	Number of Loads	Wash Water (L)	Rinse water (L)	Energy to heat wash water (kWh)	Energy to heat rinse water (kWh)
1715	593.55	1020.92	397.6839	75.15283	35.65185
1848	639.58	1100.09	428.5247	80.98101	38.41669
1509	522.26	898.29	349.9155	66.12573	31.36947
1474	510.15	877.46	341.7995	64.592	30.64188
1621	561.02	964.96	375.8867	71.03367	33.69776
989	342.29	588.74	229.3349	43.33886	20.55958
854	295.57	508.38	198.0304	37.42304	17.75317
1715	593.56	1020.92	397.6839	75.15283	35.65185

Table 4.10: Projected dishwasher (CL44e) water usage per day in Howe Hall Cafeteria, based on cafeteria usage data from February 8-14 and dishwasher loads per student (values as seen in Table 1).

Number of Students	Number of Loads	Wash Water (L)	Rinse water (L)	Energy to heat wash water (kWh)	Energy to heat rinse water (kWh)
1939	671.08	1154.26	449.63	84.97	40.31
1630	564.14	970.32	377.97	71.43	33.88
1539	532.64	916.15	356.87	67.44	31.99
1758	608.44	1046.52	407.65	77.04	36.55
1101	381.05	655.41	255.31	48.25	22.89
1112	465.90	801.34	312.15	58.99	27.98
973	407.66	701.17	273.13	51.62	24.49
1939	671.08	1154.26	449.63	84.97	40.31

Table 4.11: Projected dishwasher (CL44e) water usage per day in Howe Hall Cafeteria, based on cafeteria usage data from March 8-14 and dishwasher loads per student (values as seen in Table 1).

Number of Students	Number of Loads	Wash Water (L)	Rinse water (L)	Energy to heat wash water (kWh)	Energy to heat rinse water (kWh)
1735	600.48	1032.83	402.32	76.03	36.07
1513	523.65	900.67	350.84	66.30	31.45
1566	541.99	932.22	363.13	68.62	32.55
1499	518.80	892.34	347.60	65.69	31.16
1382	478.31	822.69	320.47	60.56	28.73
824	345.23	593.80	231.31	43.71	20.74
811	339.79	584.43	227.66	43.02	20.41
1735	600.48	1032.83	402.32	76.03	36.07

3.5 *Other Observations*

It was discovered that Howe Hall and O'Brien Hall are scheduled to get new dishwashers in the 2010/2011 school year. The new machines will be Hobart Warewasher CL44e models. These models use 1.72L of water per wash cycle and .69L per rinse cycle (Hobart Corporation, 2008).

Various observations outside of the scope of the informal interviews and direct measurements were made during the course of this project. One observation of special interest was the fact that cafeteria workers often ran the dishwasher even though it was not full. It was noticed by researchers that the spray pipes in Shirreff Hall often ran when they were not being used, and even when they were is use, only a fraction of the water actually came in contact with the dishes that were being rinsed.

Table 5.1: Average number of students per week, total number of dishwasher loads per week, total volume of water consumed per week, total energy consumption in water heating per week.

	Volume of water consumed (L)	Energy consumed (kWh)
Risley	36430	2667
Howe	60960	4242
Shirreff	39368	2192
O'Brien	16307	1344

Table 6.1: Bunker-C requirements for energy generation to run Shirreff, Howe and Risley Halls cafeteria dish-pits, and associated CO_2 emissions per 28-week school year.

	Volume of water consumed (L)	Total Energy Use (kWh)	Volume of Bunker-C (L)	Mass of Bunker C (kg)/wk	Mass of CO_2 (kg) per week	Mass of CO_2 (kg) per year	Cost ($)
Risley	36430	2667	224.27	219.78	688.59	19281	?
Howe	60960	3634	305.58	299.47	938.26	26271	?
Shirreff	39368	2192	184.32	180.64	565.95	15847	?
total	136758	8493	714.17	699.89	2192.81	61399	?

Table 6.2: Oil requirements for energy generation to run the O'Brien Hall cafeteria dish-pit, and associated CO_2 emissions per 28 week school year.

Total Energy Use (kWh)	Volume of oil (L)	Mass of oil (kg)	Mass of CO_2 (kg) per week	Mass of CO_2 (kg) per year	Cost ($)
1344	119.22	108.50	349.44	9784.32	?

4. Discussion

The purpose of this project was to assess the current water and energy use in Dalhousie's cafeterias dish-pits in order to determine the most effective reduction strategies for these resources. The cafeteria that used the most water was Howe Hall, whose water use was 136267 L/week, almost 4 times more water than required in any other cafeteria. Howe Hall also used the most energy, totalling 9402 kWh/week, more than all other cafeterias put together. Shirreff Hall cafeteria has sinks, sprayers, and pipes used to pre-wash dishes; the total water consumption of these apparatus is 23188.5 L/week, which is 58% of that cafeteria's water use. This information regarding Shirreff Hall's very high non-dishwasher water use is remarkable due to the variability in the flow rate of the sprayer as seen in Table 3.5.

Most of Studley Campus gets its energy supply from Dalhousie's own bunker-C steam generator. Combustion of 1 litre (L) of this fuel source creates 3.13 kg of CO_2, and 11.89 kWh of energy. Bunker-C currently costs approximately XXX$/kg. The energy requirements of the dish-pits of Shirreff, Howe and Risley Halls as shown by this study would require 1175 kg of bunker-C to be burned each week. The combustion of this amount of bunker-C would create annual emissions of 105201 kg of CO_2 .

O'Brien Hall is located on Sexton Campus, it does not operate on the same energy system as the other cafeterias in this study. Instead, it is powered by oil, which costs XXX$/litre. Water in O'Brien Hall is heated by the combustion of oil. The combustion of one litre of oil creates 2.93kg of CO_2 and 10.46 kWh of energy. Based on the findings of this study, to supply O'Brien's cafeteria with enough energy to heat its water, 119L of oil must be consumed each week, creating annual CO_2 emissions of 9784kg. Each of these fuel sources also creates SO_2 as a by-product of combustion, however calculating the exact emission levels is difficult due to the variable level of sulphur in different oil sources (Aubrecht, 2006).

The standard temperature for rinse water in industrial dishwashers as per Government of Canada regulations is 82ºC (Government of Canada, 2000). O'Brien, Shirreff and Howe Halls' dishwashers all have average rinse temperatures higher than this industry standard. For example, Shirreff Hall's dishwasher has an average rinse temperature of 83.1ºC, 1.1ºC higher than the standard. The extra heat added to the water translates directly into the unnecessary use of energy.

The emissions levels and costs are a low-ball estimate due to the nature of Dalhousie's integrated bunker-c/steam energy system. Levels of efficiency were not taken into account in these calculations, therefore the actual cost and CO_2 output levels are likely higher than estimated here.

CO_2 is a recognized green house gas, which is the most targeted contributor to global warming. SO_2 is a component of smog, which is a common affliction in many cities. It is also a major cause of acid rain, which can be damaging to agricultural operations, watersheds, and the built environment. This airborne chemical is especially damaging in Nova Scotia, as wind patterns drag much pollution from the United States into southern and central Nova Scotia through the long-range transport of atmospheric pollutants (Freedman, 2010).

The findings of this study will allow Dalhousie Facility Management to make effective decisions about how the University's cafeterias can reduce their carbon footprint and reduce their environmental impacts in accordance with the Halifax Declaration signed in 1991 and the Talloires Declaration signed in 1999 (Office of Sustainability, 2009). Because the most significant uses of water and energy were identified, Facilities Management now has the knowledge that will allow them to allocate time and effort into lessening the impacts of the most wasteful of practices. The benefits of these findings also extend to other commercial cafeterias with similar dish-pit practices.

Unfortunately, the calculations displayed in table 6.1 and 6.2 did not work out as planned. The information required to accurately represent the economic costs and green house gas emissions of burning Bunker C fuel and heavy oil was not available to the researchers within the timeframe of this project. In order to make realistic estimations for these values, researchers would require the efficiency of Dalhousie's Bunker C/steam generator system, the 2010 price of Bunker C, the efficiency of O'Brien Hall's oil fire heating system and the 2010 price of heavy oil. Due to the lack of proper information, the assumptions made regarding the monetary cost and green house gas emissions must be disregarded.

5. Conclusion

During the research stages of this project, it was discovered that Howe Hall and Obrien Hall were scheduled to get new dishwashers in the 2010/2011 school year. The new washers are Hobart Warewasher CL44E. The manufacturer indicates that these washers use 50% of the amount of water as Dalhousie's current models (Hobart Cle Warewashers, 2008). The installation of such a machine would be Obrien Hall's primary means of reducing resource consumption in the cafeteria, because the dishwasher is currently the highest consumer of water. Cutting O'Brien's dishwasher water use in half would reduce its oil use by

A second option for Obrien Hall to reduce resource consumption would be to run an education campaign informing cafeteria users of the water and energy required to run a cafeteria. This campaign should include ways that students can help to reduce the cafeteria's resource consumption, such as reusing dishes if they take second helpings of a meal or beverage. This would reduce the number of dishes that require washing, and thereby minimize the resource consumption of the cafeteria.

Risley Hall's water use is largely attributed to the dishwasher. The most effective method of water and energy reduction would be to replace the current dishwasher with the Warewasher CL44E machine which is being installed in Howe Hall and Obrien Hall in the 2010/2011 school year. This model is estimated to use 50% less water than the current dishwasher in Risley Hall.

By installing the new dishwasher in O'Brien, energy would be reduced by 629 kWh per week. This translates into 163 kg less CO_2 and an economic savings of $XXX (The Engineering Toolbox, 2005a). A new dishwasher in Howe Hall would translate into energy savings of 1270 kWh per week, and water savings of 9400L per week. Hobart Corporation spokesperson Bob McGillivary indicated that the purchase and installation of a new dishwasher system would cost approximately $50 000, and the Hobart Corporation website shows that the average savings with a WareWasher CL44E is $9192 per year (Hobart Corporation, 2008). Because Dalhousie's cafeterias only run 8 months of the year, the approximate savings in each cafeteria would be $6100 per year. With these savings, the new machine could pay for itself in about 8 school years.

Shirreff Hall presented the most complex dish-pit system of all the cafeterias on campus. The non-dishwasher water use totalled almost half of the dish-pits water use, due to the use of sinks, a sprayer, and a spray-pipe system used to rinse dishes before they were washed. The spray-pipe system used to rinse dishes as students bring them in is exceptionally wasteful. The need for pre-rinsing dishes could be greatly reduced by simply scraping all foodstuffs from the dishes prior to loading them in the dishwasher. In addition, the majority of the water that exited the pipe sprayers did not actually come in contact with the dishes that were meant to be rinsed. Ultimately, the need for the pipe system could be highly reduced by scraping dishes, and replaced entirely by simply using the sprayer located next to the sink.

The sinks in Howe Hall are a focal point of possible improvements, based on their enormous water consumption. The sinks are refilled every 30 minutes during the operating hours of Howe Hall Cafeteria. The first sink, used for washing, needs to be refilled more often than the rinsing and sanitizing sinks because the water becomes quite greasy from the dishes. The rinsing and sanitizing sinks, however, do not need to be refilled as often because the water does not get greasy or dirty as quickly as the washing sink. The primary recommendation to remedy the excessive water use in this case is to only refill the sinks as needed. For example, if the rinsing sink alone were refilled every hour instead of every 30 minutes, it would reduce Howe's water consumption by approximately 7000L (11%) per week.

The standard temperature for rinse water in industrial dishwashers as per Government of Canada regulations is 82ºC (Government of Canada, 2000). Howe, Shirreff and O'Brien Halls dishwashers all have average rinse temperatures higher than this industry standard. The extra heat added to the water translates directly into the unnecessary use of energy. Regular maintenance of the cafeterias' dishwashers would allow them to perform in accordance with Government regulations, without expending excess energy.

A more campus-wide solution to water waste would be to implement a grey-water use system, utilizing the waste water from dish-pits in activities that do not require potable water, such as flushing toilets. The implementation of such a system would require a physical, environmental and economic feasibility study, which could perhaps be completed as a future student project in ENVS 3502.

Another campus-wide initiative to reduce energy costs in cafeteria would be the implementation of drain water heat recovery systems. Drain water heat recovery systems work on the principle of thermal conductivity, transferring the thermal energy of waste water to incoming water. This thermal transfer increases the temperature of the incoming water (in some cases up 14 degrees Celsius) and can represent a significant reduction in energy costs to heat incoming water (RenewABILITY Inc, n.d.). The heat transfer system works by wrapping copper pipes with incoming water around the outflow pipe. There is an optimal pipe length of three to six feet; the transfer efficiency fluctuates with not only length but also diameter of the pipe. Drain water thermal energy transfer is most efficient when it is instantaneous, as in the case of cafeteria dishwashers where there is a near constant outflow of heated wastewater.

For instances where operations do not incur constant wastewater outflow, there is potential for latent thermal energy transfer. Bob Bolin from Champlain College in Burlington, VT, USA was interviewed about the system that he designed, created and implemented at the cafeteria at the College. Mr. Bolin implemented a small thermal energy recovery system because of apprehension concerning the success of the project, but was happily surprised to find that the system was incredibly efficient and produced excellent results with real savings in terms of decreased energy use to heat water. Bob designed his system to accommodate for latent thermal energy transfer and despite the drop in transfer efficiency, the project was successful (Bob Bolin, Champlain College, Phone Interview- Feb 12, 2010). Further study should be done on the feasibility of implementing a drain water heat recovery system for each of the cafeterias at Dalhousie.

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Appendix A - Calculations

Equations for water usage per day models:

Equations for energy and cost:

1. Mass (kg) of Bunker-C required to run Studley Campus cafeteria dish-pits (www.labo-analytika.com, 2000; The Engineering Toolbox, 2005b)
    - [Energy density of Bunker C(42808.43 kj/L)]*[Density of Bunker-C (0.98kg/L)*[0.0002778 kWh/kJ]*[energy required by dish-pits as per table 5.1 (kWh)]

2. Mass (kg) of CO_2 produced by amount of Bunker-C burned (Carbon Dioxide Information Analysis Centre, 2010)
    - $CO_{2i}=P_i(C_i)$ where CO_{2i} is the amount of carbon released by combustion of bunker C, P_i is the consumption of bunker C in kg and C_i is the carbon content in kg per kg of fuel. C_i for bunker C is .855.
    - Mass of CO_2 released= CO_{2i}/[molar mass of atomic carbon]* [molar mass of CO_2]

3. Mass and Volume of oil required to run O'Brien Hall cafeteria dish-pit (The Engineering Toolbox, 2005b)
    - [Energy required as per Table 5.1]*[11.27kWh/L oil combusted] = Volume of oil required (L)

4. Mass (kg) of CO_2 produced by mass of oil burned (The Engineering Toolbox, 2005a)
    - [kWh of energy required as per table 5.1]*[.26 kg CO_2 produced/kWh produced by oil combustion]

Appendix B- Photos of Dish-Pits

Figure 1: Howe Hall's Dish-pit. The arrow points to the sprayer, the dishwasher is circled.

Figure 2: Risley Hall's Dish-pit. The arrow points to the sprayer, the dishwasher is circled.

Figure 4a: This figure displays the dishwasher and sprayer in O'Brien Hall Cafeteria.

Figure 4b: From left to right, the washing, rinsing and sanitizing sinks in Howe Hall Cafeteria.

Figure 4c: Shirreff Hall's pipe sprayers. The water exiting the pipes barely comes into contact with the dirty dishes.

Figure 4d: Risley Hall's sprayer, located within the sink and next to the dishwasher.