UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Synthesis Report: UBC Water

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INTRODUCTION

As an emerging leader in sustainability, the University of British Columbia has started to concentrate efforts to meet its goal of reducing campus GHG emissions by 100% by 2050[1]. Among these efforts are addressing campus water sustainability issues. The UBC Campus Sustainability Office is currently in the process of developing a Waste and Water Action Plan that will outline concrete targets, goals and actions for campus water sustainability. Over the next year, this plan will be developed by a working group consisting of stakeholders from across the campus, and revised based on feedback from the community. Although there are no concrete goals defined for water management practices and sustainability yet, there is a general sentiment that:

(a) water consumption needs to decrease on campus;
(b) UBC should manage its water supply to alleviate pressure on municipal systems;
(c) the environmental impacts of the campus water system needs to be decreased, and;
(d) the UBC population needs to become more connected with the land and campus water resources[2].

In 2009, UBC's Point Grey Campus consumed around **4.3 billion liters of potable water** to service a university campus with over 50,000 students, faculty and staff[3]. This is equivalent to the water in 1,720 olympic-sized pools![4]

UBC's Water Source

UBC Utilities purchases potable water from Metro Vancouver every year at a cost of approximately $2.5 million at 60 cents per cubic meter[5]. This water comes from the Capilano and Seymour Watersheds in the North Shore and travels downstream by gravitational force to the Lower Seymour Conservation Reserve where the new Seymour-Capilano Treatment Plant will, once completed in the next three years, use filtration, UV light, and a minimal amount of chlorine to cleanse the water[6]. After travelling through this area, the water continues to run down through a series of water pipes, ultimately flowing into the Sasamat Reservoir in Pacific Spirit Park. From there, water travels to two main supply points: the Powerhouse Booster Pump Station on 2040 West Mall and the 16th Avenue lower pressure zone connection; both of which continually pump water to all of UBC. There are no storage facilities on the UBC campus[7].

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[1] Climate Action. *UBC Sustainability Initiative.*Retrieved from http://sustain.ubc.ca/climate-action.
[2] Water. *UBC Sustainability Initiative*. Retrieved from http://sustain.ubc.ca/campus-sustainability/campus-themes/water.
[3] Giratalla, Waleed. *Water Action Plan: UBC & Regional Context.* UBC Institute for Resources, Environment and Sustainability. Guest Speaker Presentation. Retreived from http://www.ires.ubc.ca/courses/undergraduate_courses/apsc364-student-area/weekly-schedule-readings/.
[4] Olympic-size swimming pool. Wikipedia. Retrieved from http://en.wikipedia.org/wiki/Olympic-size_swimming_pool.
[5] Ibid, Giratalla.
[6] Seymour-Capilano Filtration Project. *Metro Vancouver*. Retrieved from http://www.metrovancouver.org/services/constructionprojects/water/pages/seymourcapilano.aspx.
[7] Urban Systems. *University of British Columbia 2010 Integrated Water Master Plan.* Retrieved from http://www.ires.ubc.ca/courses/undergraduate_courses/apsc364-student-area/group-projects/

End-use of UBC Water

A recent water audit conducted for the UBC Sustainability Office measured the estimated composition of UBC's average water demand by type of use (Figure 1)[8].

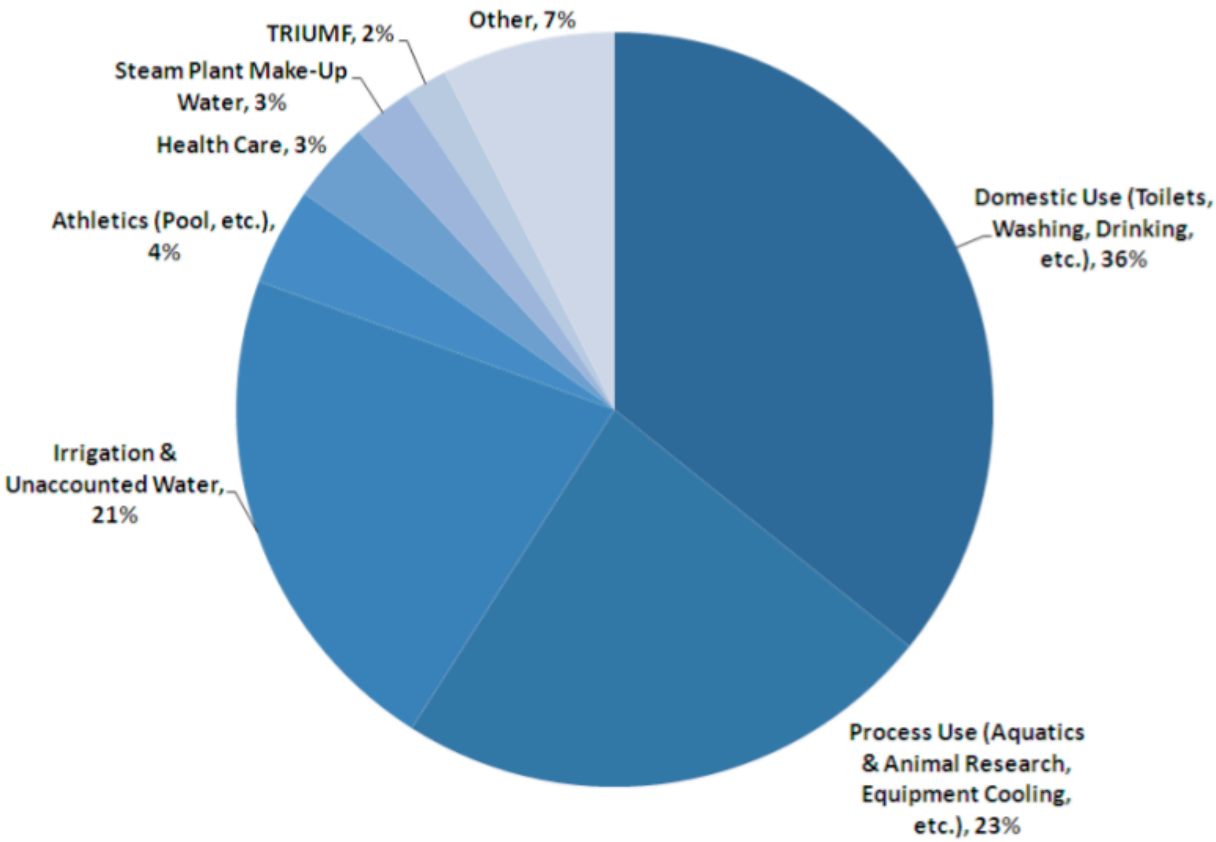

FIGURE 1: Estimated composition of UBC's average water demand.

As Figure 1 indicates, of the 4.3 billion litres of water UBC typically consumes, areas of significant water consumption include consumer demand, academic facility use, and irrigation. There is an unknown percentage of UBC's total water consumption that is unaccounted for (i.e. water lost somewhere in the system)[9]. Also, Nearly half of UBC's water consumption is attributable to a base flow (water that is in constant use for purposes like equipment cooling)[10].

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[8] Giratalla, Waleed. *Water Action Plan: UBC & Regional Context.* UBC Institute for Resources, Environment and Sustainability. Guest Speaker Presentation. Retreived from http://www.ires.ubc.ca/courses/undergraduate_courses/apsc364-student-area/weekly-schedule-readings/.

[9] Ibid. *University of British Columbia 2010 Integrated Water Master Plan.*

[10] Oberg, Gunilla. *Project Brief: Water Conservation at UBC Point Grey Campus*. UBC Institute for Resources, Environment and Sustainability. Group Project Outline. Retrieved from http://www.ires.ubc.ca/courses/undergraduate_courses/apsc364-student-area/weekly-schedule-readings/.

Wastewater Management

Every year, UBC sends approximately 3.8 billion liters of wastewater to the Iona Waste Water Treatment Plant in Richmond, costing a total of around $1.5 million at 40 cents per cubic meter. Campus wastewater travels through a 20-30 kilometer underground pipe system where the water is treated at the Plant and then released to the ocean[11].

Overview

In total, UBC spends approximately $4 million on its water supply system annually. Future projections show that "the value of the capital improvements required to meet existing system deficiencies and the growth outlined in the Campus Plan" for potable water is approximately $2,408,000 for the 10 year period from 2010 to 2020. A recent study highlighted that nearly 50%, or $2.6 million, of water and sewer pipe upgrades could be avoided by reducing water consumption at UBC by 25%[12].

In regards to environmental sustainability, while new LEED certified buildings on campus are more water efficient and programs like EcoTrek have substantially reduced water consumption on campus through extensive retrofits, there is still more that can be done to decrease environmental impacts. For example, decreasing demand on the municipal water supply system and the Iona Wastewater Treatment Plant will decrease GHG emissions and energy consumption implicated in pumping. Also, lowering consumer demand will result in lower GHG emissions and energy consumption implicated in the pumping, heating and treatment of the water all along the system[13].

In regards to social sustainability, UBC currently does not have robust community engagement and behavior change programs. Small-scale engagement opportunities already exist through some of UBC's green building features and the Campus Sustainability Office Sustainability Coordinator program, for example, but there are no large-scale, demand-side programs yet[14].

Evidently, UBC will need to address both demand and supply management issues in order to decrease both environmental and economic costs of the campus water system in the long term. In our selection of options we have less of an emphasis on supply management since we felt that the water management technologies have been much more explored than behavioral strategies in the world at large, and thus, wanted to leverage the latter.

In addition to selecting more behavioral-focused options, we wanted to investigate options we personally were interested in exploring.

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[11] Urban Systems. *University of British Columbia 2010 Integrated Water Master Plan.* October 2010. Web. 20 Jan. 2010.
[12] Ibid.
[13] Water. *UBC Sustainability Initiative*. Retrieved from http://sustain.ubc.ca/campus-sustainability/campus-themes/water.
[14] UBC Sustainability. *UBC Sustainability Initiative*. Retrieved from http://sustain.ubc.ca/.

WATER CONSERVATION OPTIONS

Method

The development of the technological, infrastructural and programmatic options outlined in this report were informed through three main modes of idea generation: (a) general internet searches, (b) review of campus sustainability initiatives in the AASHE (Association for the Advancement of Sustainability in Higher Education)[15] database, and (c) team brainstorming based on existing knowledge of the water management systems at UBC.

Discussion of selected options will include all or some of following information:

- Description of each technology/infrastructure/program
- High-level cost implications (including capital costs and projected cost savings)
- Description of the state of development of the technology and sites where this option has been implemented
- Environmental impacts
- Co-benefits to UBC
- Research and academic potential of this project
- Potential controversy of the option
- Implicated stakeholders both on and off campus

The information listed here not included in each of our option descriptions either do not apply, or they are explained in our assessment grid (see Appendix A).

List of proposed options in this document:

1. Upgrading to Water-Conserving Showers

2. Using Greywater for Toilet Water in the UBC Aquatic Centre

3. Student Residence Water Conservation Competition

[15] Association for the Advancement of Sustainability in Higher Education. Retrieved from http://www.aashe.org/ (Database is only accessible to membership).

Option 1: Upgrading to Water-Conserving Showers

Description

This solution integrates three water conservation components: (1) fixing leakages in showers[16], (2) replacing existing shower heads with low flow showerheads, and (3) installing timed shower on/off knobs that automatically shut off after a certain amount of time. In regards to (2), low flow showerheads have been installed on campus through the Eco-trek program starting in 2001[17], however we are unsure as to whether this has been done for all campus showers, and believe that there may even be more efficient and water-conserving low-flow showerhead technology available, such as low-flow aerators[18]. Indeed, when our team investigated the flow rate of showerheads in Marine Drive Residence and Thunderbird Residences, we found that they operate at approximately 2.1 gallons per minute (GPM).

The development and implementation of this solution would mainly involve UBC Utilities, Housing and Conferences, and any external companies that could provide the shower technology.

High-level cost implications

Costs would include the purchase of the timer technology, materials required for repairing leakages, and labor wages for installation and maintenance. A less expensive alternative to replacing shower on/off knobs would be attaching removable hourglasses timers to shower stall walls. The following is a table of sample costs:

Material	Cost
Earth Massage Showerhead - 1.5 GPM	$14.95 [19]
Shower Hourglass Clock	$0.6 [20]
Teflon Tape	$5 (rough estimate)
Wages	$15/hr – takes around 10 minutes to finish one washroom. Cost = $2.5/shower
Total/Shower	**$23.05**

Currently the UBC Vancouver campus houses 29% of undergraduate students.[21] UBC hosts about 24 thousand full time undergraduate students[22]. If we assume that there is one shower per 4 people then, considering only full time undergraduates, we would have about:

Showers = 24K * 29% * (1/4) = 1,800 shower heads

Cost of Upgrade = 1,800 Showers * $23.00 ~ $41,400

[16] This Old House. *How to Troubleshoot a Leaky Shower*. Retrieved from http://www.thisoldhouse.com/toh/video/0,,20047026,00.html
[17] The College Sustainability Report Card. *Report Card 2010: University of British Columbia.* Retrieved from http://www.greenreportcard.org/report-card-2010/schools/university-of-british-columbia/surveys/campus-survey
[18] Earth Easy. *Low-Flow Aerators / Showerheads*. Retrieved from http://eartheasy.com/live_lowflow_aerators.htm#2e
[19] Ibid
[20] Alibaba.com. *Shower Timer 2~5 minutes Save Energy and Water, Sand Timer, Hourglass Shower Timer*. Retrieved from http://www.alibaba.com/product-gs/233043196/Shower_Timer_2_5_minutes_Save.html
[21] UBC Public Affairs. *Student housing gets huge boost at UBC's Vancouver campus*. Retrieved from http://www.publicaffairs.ubc.ca/2011/02/08/student-housing-gets-huge-boost-at-ubc%E2%80%99s-vancouver-campus/
[22] The Pair Office. *Planning & Institutional Research*. Retrieved from http://pair.ubc.ca/statistics/profile/quickfacts2009.pdf

Cost of Water (old shower heads 2.1 gpm) = 65.1L/1 shower[23] * 1800 showers * 4 people/shower * $1.00/cubic meter water * (1 cubic meter water/1000L) * 365 days/year = $171,082/year

Cost of Water (new shower heads with 1.5 GPM) = $171,082/year * (1.5/2.1) = $122,202/year

Savings = $171,082 - $122,202 = $48,880 (does not include upgrade cost)

Technology options

Global Network Solutions LLC[24] and Aquaflow Distributors Co., makers of The Shower Manager and Shower Timer respectively,[25] are examples of companies that supply timing devices for showers. For our project we only investigated the cost of a removable hourglass shower timer, as we would suggest that the university try a lower-cost, lower-risk model first in order to gather data about behavioral implications. If the water savings proves successful or unsuccessful, the university should contemplate installing on/off handles that have built in timing devices that automatically shut off the shower after a certain amount of minutes.

Environmental impacts

Lower consumption of water entails less energy required to pump the water through UBC pipes, and less energy required to heat the water. Using the above calculations, we estimate the amount of water saved to be:

Water Saved/year = (65.1L – 65.1L * (1.5/2.1)) * 1800 showers * 4 people/shower * 365 days/year = 48,880,800 L/year

Other environmental impacts are negligible, but there are also energy, GHG emissions, natural resource extraction and environmental degradation implications in installing new technology.

Potential controversy

The removable hourglasses have the potential of being damaged or stolen, which would result in an annual replacement cost (both financially and environmentally). Also, residents might take longer showers if they feel that the showerhead is not outputting enough water.

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[23] (Based on an average shower duration of 8 minutes) – Residential Shower and Bath Introduction. Alliance for Water Efficiency. Retrieved from http://www.allianceforwaterefficiency.org/Residential_Shower_Introduction.aspx.
[24] Global Network Solutions LLC. *The Shower Manager*. Retrieved from http://www.showermanager.com/
[25] AquaFlow Distributors Co. *Shower Timer*. Retrieved from http://showertimer.com.au/

Option 2: Using Greywater for Toilet Water in the UBC Aquatic Centre

Description

This idea involves reusing wastewater from showers and sinks in the UBC Aquatic Centre (and possibly pool facilities) for toilet water. The development and implementation of this option would involve UBC Aquatic staff, UBC Plant Operations, UBC Utilities, the Campus Sustainability Office and any external companies that would provide the necessary technologies, materials and labor capacity.

High-level cost implications

We are currently unfamiliar with how grey water systems work in different scenarios and what the set-up of the Aquatic Centre facilities is. More research would need to be conducted to illuminate this. The proposed solution would require the infrastructural change of the aquatic center facilities, and that will include installing pipes that will direct the grey water to toilets in and outside of the aquatic center buildings. This would require labor costs and material costs. Exact costs of infrastructural change have not been determined. However, we can estimate the amount of savings we would be able to achieve after implementing the solution.

The Aquatic Center consumes about 4L of water per second, which includes evaporation, showering, toilet using, etc.[26] If we assume 15 hours of operation for all days of the year[27], and if we assume that our new system will save 0.5L/second, we will be to save 9,855,000L of water annually.

Thus, UBC would save:

9,855,000L/year * 1m^3/1000L * 60 cents/m^3 = $5,913/year

Environmental impacts

It was beyond the capacity of our team to find concrete numbers on the environmental impacts for this option, but it is our opinion that the environmental impacts and economic costs are relatively high compared to the amount of water the greywater technology would save.

Research and academic potential

Student research capacity could be harnessed to investigate the infrastructural feasibility of this option, as well as to conduct sustainability assessments of the impacts during and after implementation.

Potential controversy

Infrastructural changes to the Aquatic Centre facilities will likely require the pool, or areas of the pool, be shut down for some time. This might be problematic for community and university activities that occur on regular basis. There is a danger of mixing potable water with waste water while piping. Due to this risk, it is important for any plumber to have a full understanding of regulations and of potential hazards.

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[26] W. Giratalla, personal communication, March 2, 2011.
[27] *Indoor Pool Schedules*. UBC Aquatic Center. Retrieved from http://www.aquatics.ubc.ca/schedule/indoor-pool.php.

Option 3: Student Residence Water Conservation Competition

Description

Conservation education in the university setting must begin when students first arrive at UBC in order to be most effective. Therefore, we propose that water conservation education programs should begin with residences on campus, two of which are used to house first year UBC students. UBC offers eight student residence areas: Totem Park, Place Vanier, Walter Gage, Rits-UBC House, Thunderbird and Acadia Park[28]. We suggest the introduction of a building-to-building conservation competition within each residence area, in which, for example there could one champion per semester and one overall winner amongst all residences per year. The winner at the end of each semester would be awarded with a house-wide prize, like pizza or ice cream, and would be recognized in various campus and non-campus media outlets. At the end of the entire Winter Session (beginning of April), the conservation achievements of each house from Term 1 and 2 could be combined and compared with the achievements from the houses of all of the 8 residences on UBC campus.

High-level cost implications

The competition would be run by Residence Advisors (R.A.'s), whose wages are already paid by UBC Housing and Conferences. There is also always a large pool of funds for R.A.'s to run events, so the provision of awards would entail minimal cost. In order to track water usage and develop promotional and general event materials, extra capacity and financial support might need to be provided by the Campus Sustainability Office.

Do it in the Dark is an energy conservation residence competition where UBC competed with 38 other American universities. UBC took second place overall and was able to save more than 16% of energy within 20 days[29]. This could be used to show potential of energy and money savings possible from such competitions, and analogously estimate possible savings from water conservation competitions.

Where the option has been implemented

Residence competitions in general are implemented by many universities; however there are two universities competitions we could find that integrate water conservation: Water Wars at Denison University in Granville, Ohio[30] and Eco-Madness at the University of Connecticut in Storrs, Connecticut[31]. It is worth noting that the winning residence of the Water Wars was able to conserve more than 10% of its water usage[32]. Also, UBC will be doing annual energy competitions in residence, the first one having transpired in November 2010, as mentioned[33]. Integration into this existing program could be explored.

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[28] *Choose the Right Residence*. UBC Housing and Conferences: Student Housing: Choose the Right Residence. Retrieved from http://www.housing.ubc.ca/student-residences-van/choose-the-right-residence
[29] *Do It in the Dark: Part 2*. UBC Sustainability. Retrieved from http://www.sustain.ubc.ca/sustainability-ubc/do-it-dark-part-2
[30] *Water Wars*. Denison University. Retrieved from http://www.denison.edu/sustainability/water_wars.html
[31] *Eco-Madness in North, Northwest, Towers, and Shippee*. Retrieved from http://www.ecohusky.uconn.edu/ecomadness.htm#c
[32] *Water Wars*. Denison University. Retrieved from http://www.denison.edu/sustainability/water_wars.html
[33] *Do It In The Dark*. UBC Sustainability Initiative. Retrieved from http://www.sustain.ubc.ca/dark

Co-Benefits to UBC

By educating students on water conservation practices, we expect that they will be more likely to continue these practices throughout their lives and beyond their time at UBC. We are hoping that sustainable behavior will become habits that will save enormous amounts of water over time.

Research and academic potential

Student research projects could investigate existing competition models and ideas, as well as the effectiveness of the competitions.

DECISION-MAKING FRAMEWORK

The development of a framework for project assessment can be a challenging task, particularly when attempting to take into account the economic, social and environmental impacts that might dictate a project's eventual success. Ultimately, the purpose of our assessment matrix, found in Appendix A, is to facilitate UBC's sustainability-project evaluation process. The matrix will help UBC decision-makers to evaluate different sustainability projects against a variety of indicators that represent economic, social and environmental considerations, in order to identify the "best" solutions. However, it is important to note that the notion of the "best" project changes depending on the context under which the evaluation is done. For example, if the evaluators place emphasis on one criterion over others, this can produce results that reflect this bias.

FIGURE 2: Sustainability Stool

In order to ensure that our criteria are representative of all the dimensions of sustainability, we utilized the three-legged stool analogy. (See Figure 2) The analogy suggests that neglecting one of the legs of the stool would cause the stool to fall over, meaning that sustainability would fail without the balance between environmental sustainability, economic feasibility and social prosperity. This is in line with UBC's definition and vision, in which sustainability is "a societal conversation about the kind of world we want to live in, informed by some understanding of the ecological, social and environmental consequences of our individual and collective actions."[34] Therefore, we derived criteria and indicators from all three dimensions of sustainability.

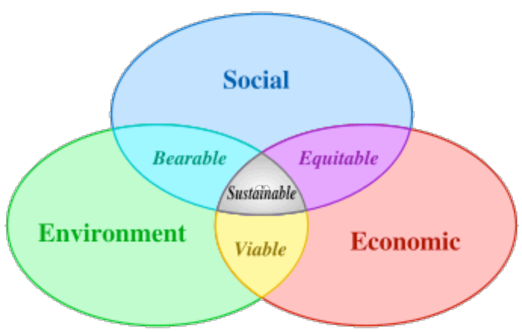

FIGURE 3: Venn Diagram of Sustainability

Initially, we attempted to categorize our criteria in the Venn diagram schema (Figure 3) as a way to help identify criteria that not only fit into one of three aforementioned dimensions of sustainability, but also the criteria that fall somewhere in-between. For example, 'GHG emissions' is a criterion that fits logically into the economic sphere, however the use of the Venn diagram made us realize that GHG emissions have implicated economic and social costs, too. Thus, we came to understand that the Venn diagram is an excellent systems-thinking tool, allowing the analyzer to illuminate how the components of sustainability are not only individually connected to sustainability (as shown by the three-legged stool analogy) but are also deeply interconnected.

We identified three of our criteria as 'deal-breaker' or 'most important' criteria, one from each element of the three-legged stool: Water Conservation, Governance and Economic Feasibility. In other words, we placed special emphasis on the results of these criteria when completing our assessment of the three options. These criteria were chosen as deal-breaker criteria based on what we understand will be UBC's most important decision-making factors, as well as what we deemed vital to consider.[35] Evidently, UBC will ultimately make choices based off of what will be

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[34] *Sustainability*. Retrieved from http://www.sustain.ubc.ca/
[35] *Vision & Values*. Retrieved from http://www.ubc.ca/about/vision.html

economically feasible, and will actually conserve water. We decided to choose governance as a deal-breaker criterion because we would like the university to ensure those who will be affected by significant decisions are able to participate in making those decisions, and that the appropriate stakeholders are involved in the implementation of those decisions to ensure that UBC's sustainability actions are holistic and supported by empowered people who will ultimately organize and maintain them on the ground.

Another element of our matrix to note is that sometimes the criterions were not applicable to the options, like 'Water Quality'. The objective of this criterion was to ensure all water for human ingestion meets Health Canada's Guidelines for Canadian Drinking Water Quality, but none of our options involved changing the quality of potable water.[36] The inclusion of these criterions represents our efforts to create a matrix that could be used to evaluate future water conservation projects. We wanted to have the criteria we selected be not only useful for the scope of our project, but to also represent the beginnings of an assessment tool that UBC could use to evaluate future conservation efforts.

We choose to measure our criteria using a variety of different metrics including letter grades and low-medium-high ratings associated with quantitative and qualitative ranges. Where possible, we calculated a quantitative measure to describe the performance of each project for the given indicator.

Further explanations on the objectives and justification of each individual indicator can be found in Appendix A.

[36] (2010). *Environmental and Workplace Health: Canadian Drinking Water Guidelines*. Retrieved from http://www.hc-sc.gc.ca/ewh-semt/water-eau/drink-potab/guide/index-eng.php

FINDINGS

Methodology

Step 1. Assign a 1st to 3rd place ranking to each project based on it's performance in term of that particular indicator—go through each indicator independently of all others.

Step 2. Add up the results for each solution and gauge the sum total of the rankings to obtain a preliminary understanding of which solutions scored best overall. The theory here is that a solution with a low score likely received a larger number of 1st place rankings where as a solution with a higher sum total likely received more 3rd place rankings. Although we recognize that a low sum total ranking is not enough to deem a result 'best' it does provide us with a jumping-off point from which to analyze the projects further.

Step 3. Further investigate the specific results to further identify, clarify and classify the strengths and weaknesses of each project. While doing so the evaluator must keep in mind what are the key indicators that may act as deal-breakers in the eyes of the university. As a public university UBC does strive to generate income in order to fund its projects and therefore economic considerations play a major role in decision-making.

Step 4. Re-rank the options to accommodate conclusions reached by the evaluator(s) in Step 3.

Acting as the evaluators our team reached the following ranking:

#1 Ranked Option - Student Residence Water Conservation Competition

This solution ranks first because it is the most economically feasible, the most adaptable, and it has the potential to leverage significant behavior change in regards to water sustainability, and thus resulting in significant water savings.

#2 Ranked Option - Upgrading to Water-Conserving Showers

This solution ranked second because, although the project requires some overhead costs, the amount of water that will be saved is potentially relatively substantial. It is worth noting that showering is the third most water consumptive activity in residential areas.

#3 Ranked Option - Using Greywater for Toilet Water in the UBC Aquatic Centre

This option placed as our least feasible option because it requires the most potential overhead financial costs in relation to its water conservation potential. Also, installing the appropriate infrastructure for a greywater system might interfere with the regular functioning of the pool, which receives high levels of use by multiple parties. This option might also prove challenging logistically.

RECOMMENDATIONS

Based on the above findings we have developed several recommendations for UBC when approaching water conservation decision in the future. Firstly, we recommend UBC look to undertake the integrated implementation of the #1 ranked option and the #2 ranked option. These two initiatives can work congruently to improve the amount water conserved.

Secondly, we believe the university should attempt to develop more robust public engagement and social sustainability efforts. Ideally, UBC would begin to equally emphasize some of the criterion we included under the 'social' dimension, notably governance, citizenship and behavior change. Robustness in those three areas will help encourage robustness in economic feasibility and environmental sustainability because campus members will feel that they have a role to play, leading to a culture of responsibility and motivation to advance sustainability.

Thirdly, due to a lack of quality data and knowledge concerning campus systems we made the choice to discard an option we hoped to propose originally. We felt that the option was insufficiently concrete for the purposes of our project. However, we do feel strongly that the ideas in it were interesting and important, and should be explored further by the university.

We propose that:

> (a) There should be more sustainability curriculum opportunities developed or integrated with existing courses and programs at UBC so that more people are exposed to and begin to understand water conservation issues and can help develop and propel relevant solutions.
>
> (b) That investigating the water footprint of the food served on campus might initiate some interesting conversations and ideas around what kinds of food we should actually consume at UBC, within the context of sustainability.

Finally, we believe UBC should utilize the Venn diagram approach to sustainability (as shown in Figure 3). The Venn diagram of sustainability helps to promote systems thinking; viewing sustainability in a more holistic and integrated manner.

LIMITATIONS

In regards to our data and analysis, there were three main limitations that we can identify:

First, it was difficult to find specific data as well as measurement tools that allowed us to define the scope of our criteria. Either the data we found was incomplete, inaccurate, difficult to apply to UBC, or unavailable. For example, when defining our ranges for 'low', 'medium' and 'high' for the 'water conservation' and 'closed loop system' indicators, we chose our numbers based off UBC's annual water consumption (i.e. relative to 4.3 billion litres of water, a savings of over 100 millions liters would be considerably high, perhaps). However we were limited in being able to estimate exactly how much water UBC is able to conserve. We know that there will always be water consumption and thus, it would be impossible to save 4.3 billion liters. But how do we know how much can actually be saved, especially when UBC's context will change over time?

Second, subjectivity was also a limitation of our analysis, in both the choosing of criteria, the measuring of each of our options against the indicators and the ranking of our options against each other. While our analysis is heavily influenced by our own biases, we did take into account what we believed to be UBC's primary concerns in our final recommendations.

Third, a shortfall to our analysis was the lack of capacity of our team to obtain, analyze and synthesize data. As busy students with little time to work on this project, our ability to find and present comprehensive information was limited, and our lack of expertise limited our ability to work effectively with the data we did manage to find.

In regards to our sustainability assessment method, there are three limitations that we can identify:

First, our method of ranking each of our options against each other by indicator might not necessarily the best tool for the university to use when deciding between different options, at least in isolation. We feel that it is a useful tool when combined with many other tools in the decision-making process. It helps give the analyzer a very general sense of how each option compares to one another, as well as how beneficial each option might be in the bigger picture. It does not take into account that some indicators might be more important than others; however, this might be an advantage of the tool as well, in that it somewhat eliminates potential biases.

Second, while our ranking method does give a general sense of how each option compares to one another, it may inflate that general sense. We ensured that for every set of rankings that there was a 1st, 2nd and 3rd place. For the solutions that had similar indicator scorings, we still forced a ranking of 1st, 2nd and 3rd (versus 1st, 2nd and 2nd, for example). Thus, the total sum of rankings for one solution might be more different from another solution than it really is.

Last, our method does not go into a rigorous analysis of how each option compares to one another after they have been ranked. This is partly because we did not feel like a rigorous analysis was possible, as many of our indicators were very open-ended and subjective and/or lacking concrete parameters and/or lacking data. For the purposes of our project and in the limits of our time, we felt it was most strategic for our group to concentrate on the most important indicators and the most important aspects of our options.

REFLECTIONS

Overall, our team felt like the development of this project was a positive and intellectually challenging experience. It allowed us to grapple with sustainability problems that we have never had to deal with, learn about water conservation issues, and make meaningful contributions to real problems UBC is facing.

When it came to group dynamics, we had difficulties communicating our ideas and coming to consensus at times, but generally we managed to come to terms in the end and move forward. Some of our most significant difficulties were finding times that we could all meet, using the time that we did have together productively, and being able to figure out what we needed to accomplish and how, together or apart. Part of this stems from the lack of clarity in our project instructions and the course goals, part of it stems from being unable to figure out how to get around gaps in our data, and part of it stems from confusion over what tasks or elements of our project we thought were priorities.

Although we only had 3 members in our group, we felt like the diversity among the group brought some of the strengths we needed to be effective in our work. For example, Mustafa, who is practiced in mathematics and quantitative problem solving thanks to his engineering degree, was really helpful in finding and crunching numbers.

We would like to thank the APSC 364 teaching team for doing an amazing job of organizing what must have been a really challenging pilot course on hard sustainability problems, and being supportive and helpful in our efforts throughout the course. We appreciate the opportunity to learn about sustainability in a unique and exciting way, and are grateful to contribute to the beginnings of even more awesome curriculum opportunities in the future.

APPENDIX A - MATRIX

Criteria	Indicators	Objectives	Justification	Project Options & Rankings					
				Upgrading to Water-Conserving Showers	**Ranking**	**Grey Water Reclamation in the Aquatic Center**	**Ranking**	**Student Residence Water Conservation Competition**	**Ranking**
Water Conservation	Water conserved compared to "business as usual" each year: High, Medium, Low	Decrease water consumption on UBC campus	Achieve UBC's goal to become a water net positive campus	Medium	1	Medium: (the pool wastes 4L/s). We determined on a conservative estimate of 0.5L/s that can be saved using this option, assuming a 15 hour day operation. This saves about 9.8 Million liters annually.	3	Low to Medium: This solution relies heavily on behavior change; therefore; the degree of change undertaken by participants will dictate whether this solution is able to conserve a low or medium amount of water.	2
Contribution to closed-loop water system	Magnitude of decrease in water purchased from GVRD each year. LOW (0 up to 10 million litres per year), MEDIUM (10 million - 100 million litres per year), HIGH (more than 100 million litres per year)	Decrease the amount of water UBC purchased from GVRD	This is in line with recent UBC objectives to develop a closed loop system and reduce reliance on external water sources.	Medium to High: The shower heads alone will decrease water purchased to a medium level, however, if the additional behavior change elements are successful then there could be significantly more reductions in the amount of water purchased from GVRD	1	Low	3	Medium	2
	Magnitude of decrease in wastewater sent to Iona treatment plant. LOW (0 up to 10 million litres per year), MEDIUM (10 million - 100 million litres per year), HIGH (more than 100 million litres per year)	Increase the amount of water treated on campus and decrease costs of sending wastewater to Iona.	A legitimate closed loop system requires wastewater to remain on-site	Medium to High: This project involves a beahvior change component and will its successful implementation this project would yield not only more efficient water use but also large quantities of conserved water due to changes in human behaviors, thus less water would need to travel to Iona.	1	Low	3	Low	2
	Predicted annual volume, in litres, of locally captured water as result of project option. LOW (0 up to 10 million litres per year), MEDIUM (10 million - 100 million litres per year), HIGH (more than 100 million litres per year)	Promote the capture and use of UBC rainwater project options.	In line with UBC's objective of reducing their demand on the regional water supply and ultimately achieving a closed loop water system.	N/A	N/A	Low	N/A	N/A	N/A
GHG Emissions	GHG emissions reductions: (A) Will reduce emissions, (B) Will not effect emissions, (C) Will increase emissions	Acheive a carbon net positive campus	Further UBC's GHG emission targets of reducing GHGs to 33% below 2007 levels by 2015, 67% below 2007 levels by 2020 and eliminating 100% of GHG emissions by 2050.	A	1	C: This increase emissions is the initial result of the infrastructural advancements necessary to implement this option. In the long-term this option may in fact reduce GHG emission.	3	A: A lower amount of water use, in particular hot water use, will mean less GHG emissions.	2
Energy Consumption	Energy consumption: (A) Energy use will be reduced, (B) Energy use will stay the same, (C) Energy use will increase	Reduce energy consumption	To verify that new projects adhere to UBC's Energy Management Plan to ensure accountability, maintain current energy savings and identify further conservation opportunities.	A	1	C: This increase energy is the result of the infrastructural advancements necessary to implement this option and the continual requirement of energy to run the system.	3	A	2
Life Span	Life span of project option given worst case scenario implementation: A - over 20 years, B - between 5 and 20 years C - less than 5 years	Encourages solutions that will endure for the long term and emphasizes the importance of proper implementation	Quantitative ranges are used to capture a concrete/actual understanding of longevity.	C	3	C	2	C	1
	Life span of project option given best case scenario implementation: A - over 20 years, B - between 5 and 20 years C - less than 5 years	Encourages solutions that will endure for the long term and emphasizes the importance of proper implementation	By identifying both the best and worst case scenarios we can accurately understand a projects potential lifespan. This also emphasizes that correct implementation is important because it improves longevity.	B	3	A	1	B: Althought this project could conceivably last 'forever' we gave it a 5 to 20 year life span because, ideally, this level of behavior change program will be obsolete after 20 years, in that water conservation will be more ingrained in our communities.	2
Adaptability	Adaptability: (A) Minimal to no difficulty to modify, (B) Moderately difficult to modify, (C) Very Difficult to modify	To ensure options can be adjusted and improved throughout their lifespan.	This will discourage the implementation of projects that may require costly overhaul or total replacement.	A: the components proposed for the solution are easily implementable and removable if needed.	2	B	3	A: Implementation of this solution is considered easier than implementation of water conserving showers because it is a program that can be tweaked at little environmental cost, like that which might associated in infrastructural tweaks.	1
Community Buy-In	Predicted community acceptance / buy-in of project option: (A) High, (B) Medium, (C) Low	Ensure that campus users will actually use/participate in water conservation in a desired manner	Helps in saving money and effort by gauging early acceptance/rejection by community. This will likely have to be gauged using surveys, or other investigative tools	A: Campus residents might not use the shower timer devices, but they will not necessarily 'reject' the presence of them. This would change if we are looking at the shower handles with a timing device integrated into it (buy-in might be lower).	2	C: implementation of the solution will take time and will render portions of Aquatic facilities unusable. As a well-used facility with many different users, this might pose difficulties.	3	B: Not everyone will want to participate in the competition.	1

	Potential to be viewed as innovative / cutting edge / "cool": (A) High, (B) Medium, (C) Low	Integrate more innovative, cutting edge and/or "cool" sustainability features on campus	Avoids stagnation in terms of sustainability initiatives and promotes "outside the box" thinking. Adheres to one of UBC's themes: "the university as an agent of change."	C: The shower times is an interesting and potentially useful idea, but it is doubtful that people - notably its users - will think that it is cool.	3	A: This option is more 'cool' than innovative, in that the idea of greywater is not new per se, but people might see it as a 'good thing to do'.	2	A: Fun competitions that get people together to be more sustainable is innovative and cool.	1
Economic Feasibility	Financial costs likely required for project option. (A) Low, (B) Medium, (C) High	Ensure economic feasibility and cost efficiency with relation to water savings	At the bottom line, the University must make decisions that are economically feasible.	B	2	C	3	A	1
Research Opportunity	Magnitude of research potential: (A) High (there are many research connections that exist or have the potential to be established), (B) Medium (some research connections exist or have potential to be established) (C) Low (no foreseeable research potential)	Increase prevalence of sustainability research at UBC	This will further UBC's mission to explore and exemplify sustainability teaching, learning and research.	B: Research into behavioral implications of the shower timer will be useful, but not substantial in magnitude.	3	A: Research in transferring grey water from the aquatic center to nearby building's toilets and the effects of grey water are two potential fields of research. Also, study of people's perception to using grey water for their toilets might reveal some important behavioral data.	1	A: There are several opportunities to research the effeciveness of various behaviour change events and strategies.	2
Educational value	Quality of research potential: (A) High (is timely and relevant, can potentially involve many students, etc), (B) Medium (relevant, potential to involve students is limited), (C) Low (Untimely, cannot involve students)	Increase relevant and timely research that involves more students	Student education, notably at the undergraduate level, can be inadequate at providing hands-on experience with meaningful issues	B: The behavioral component of the shower timers may provide some research opportunities.	3	B: There may be opportunities to conduct research on improving the greywater technology.	2	A: Student resident behavioral research is best conducted by student peers to attract participants. The necessary research is within the scope of a SEEDS project, as demonstrated by the one done for the Totem Park energy competition.	1
Water Quality	Does the potable water meet Health Canada's Guidelines for Canadian Drinking Water Quality (Ranking: Y/N)	Ensure all water meant for human consumption adheres to Canadian standards.	In order to ensure that everyone has equitable access to clean, safe water, meeting consistent and universally-approved standards is crucial. It is mandatory that options receive a "yes" ranking here. This criteria/indicator does not apply to our options because none of them involve tampering with potable water.	N/A	N/A	N/A	N/A	N/A	N/A
Behavior Change	% campus population interacting with water conservation option at least once each year: (A) 51-100%, (B) 21-50%, (C) 6-20%, (D) 0-5% (Note: population means all campus users including resident, students, faculty and staff members)	Ensure high engagement numbers	The more people that are engaged in conserving water, the more water conserved in the short term and potentially in the long term, as well.	B: Around 20% of students live on campus and, presumably, all of the them take showers University of British Columbia. Wikipedia. Retrieved 10 April 2011 from http://en.wikipedia.org/wiki/University_of_British_Columbia#Residences	1	D: While there will be many people who use the bathrooms at the Aquatic Pool, our option does not have any direct engagement features.	3	C: Not all students that live in residence will participate in the competition.	2
	Quality of user interaction: (A) Very frequent, (B) Somewhat frequent, (C) Infrequent	To ensure an impactful frequency of interaction	More exposure results in greater / longer lasting behaviour change.	A: Every time a student takes a shower, there will be the potential to interact with the timer	2	A	3	B: Students are able to avoid interacting with engagement programs in residence.	1
	Number of jobs created and changed: (A) More than 100 (B) Between 10 and 100, (C) Less than 10	Integrate sustainability objectives into more job descriptions and create more green jobs	Integrating sustainability behavior into job descriptions ensures long term sustainability of those behaviors among campus stewards, and provides another channel through which to proliferate sustainability values	C: There will be a few key operational staff involved in the implementation and maintenance of the system	4	C: There will be a few key operational staff involved in the implementation and maintenance of the system	3	A: Residence Advisors will have to help manage the program.	1
Technical Feasibility	Successfully implemented of similar project, or aspects of project, at another campus or residential area (Ranking: Y/N)	Ensure option is technically feasible	The results of previous attempts at similar projects will illuminate the potential issues to be aware of and allow UBC to avoid unnecessary costs.	Yes: Didn't find information of implementing the whole solution but there have been partial implementations of the solution in various residential areas.	2	No: There are many greywater technologies, but none that attempt to integrate one into an aquatic centre.	3	Yes: Please, see fuller description of option	1
Citizenship	Amount of opportunities available for community members to spend quality time together: (A) Many, (B) Some, (C) Few or None	Promote community building	Building trust and relationships further propels citizenship and opportunities for sustainable development	C	2	C	3	A	1
Governance	Foreseeable quality of engagement with stakeholders: (A) High (e.g. multiple open dialogue consultations and stakeholders present on steering committee), (B) Medium (example: one quality open dialogue consultation), (C) Low (e.g. one or no consultation available)	To engage stakeholders in decision-making, implementation and assessment process.	Those who are affected by decisions should participate in making them. This promotes both equality and holistic solutions.	C	3	C	2	A. It is necessary to engage the residence associations, as residence activities are under their jurisdiction and the advisors will be doing much of the groundwork.	1
	Appropriateness of engagement: (A) Mandatory, (B) Appropriate to a certain degree, (C) Unnecessary	Ensure appropriate stakeholder engagement	Stakeholder engagement is not always necessary. It should be proportional to the degree to which people are affected by decisions being made and appropriate to the case / context	C	N/A	B. The administrators of the Aquatic Centre will need to be consulted, as construction might interfere with pool activities.	N/A	A	N/A
RANKING TOTALS					37		40		21
FINAL RANKING OF PROJECT OPTIONS				**2nd Place**		**3rd Place**		**1st Place**	

APPENDIX B

Authorship Statement

Angela was responsible for compiling the introduction/background information, the limitations of our project, and our group reflections.

Alex was responsible for writing the overview of our assessment tool, our findings and recommendations, as well as formatting and editing our matrix.

Mustafa was responsible for compiling and completing the information for our three options.

Each of us were responsible for finishing each of our designated parts and bringing them to a final all-group meeting, where we sorted out loose ends and delegated final tasks. We all took on about a third of our criterion/indicators to do an initial revision, then Alex and Angela polished up the matrix content as a whole.

Angela and Alex took on the final compiling, major edits, and final revisions of the report, in its entirety. All group members were then given the opportunity to take one last look over the whole report in order to approve submission.