UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into New Student Union Building (SUB) Waste Stream Tracking System

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ABSTRACT

The Alma Mater Society (AMS) is designing a new Student Union Building (SUB) that aims to be more sustainable than the current SUB. As part of being more sustainable, the AMS wants to track the waste being produced by the building, ultimately leading to the goal of reducing the waste produced. The current practice of conducting waste audits* is both inefficient and expensive, and as such a more viable method of tracking waste is needed.

An alternative is to implement scales in the waste stations* that will be placed in the new SUB, measuring the amount of waste being produced in real-time. A display mounted to the waste station can give instant feedback to users. This report uses the triple bottom line approach in order to determine whether the waste tracking system is a viable alternative to the waste audit.

As part of the triple bottom line analysis, the economic, social and environmental impacts are considered. The analysis uses research reports based on feedback techniques, as well as primary sources in gathering data regarding the different hardware options.

After considering the three aspects of the triple bottom line analysis, it is determined that the waste tracking system is a viable alternative to the waste audit. However, additional investigation, particularly into the projected effectiveness of the feedback system and into different visual feedback techniques is recommended.

* This term and all subsequent terms marked with an asterisk will be found in the GLOSSARY on page 4

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GLOSSARY

LEED :	Leadership and Energy in Environmental Design, this is an accreditation board that gives buildings a sustainability rating give a point based system.
EUAC	Equivalent uniform annual cost, this is the cost per year of mainta an asset at a given interest rate. This is a useful method of comparison, as it converts costs that are scattered throughout an asset's lifetime into a constant annual cost.

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1.0 INTRODUCTION

The Alma Mater Society is designing and building a new Student Union Building for the University of British Columbia (UBC), that is both more sustainable and larger than the current SUB. Reducing the amount of waste produced by the SUB will contribute to the sustainability of the building, and in order to do this, the students and faculty need to be educated about how much waste is being produced. Currently, the only means of quantifying the amount of waste produced by students and faculty in the SUB is by conducting a waste audit. However, waste audits are very expensive and time-consuming; as such they are infrequently conducted.

As an alternative to the waste audit, scales can be added to each waste station to measure the amount of waste in each of the four solid waste streams* (organics, recyclables, paper products and other waste), and to give instant feedback as users throw away waste in real time. The AMS has requested a triple bottom line analysis on the waste scale idea in order to determine whether it is economically viable, if people will buy into the idea and be affected by the feedback and whether it ultimately results in a reduction in waste produced by the SUB.

A conceptual physical model of the waste station with waste stream bins and a display monitor is shown in the following figure.

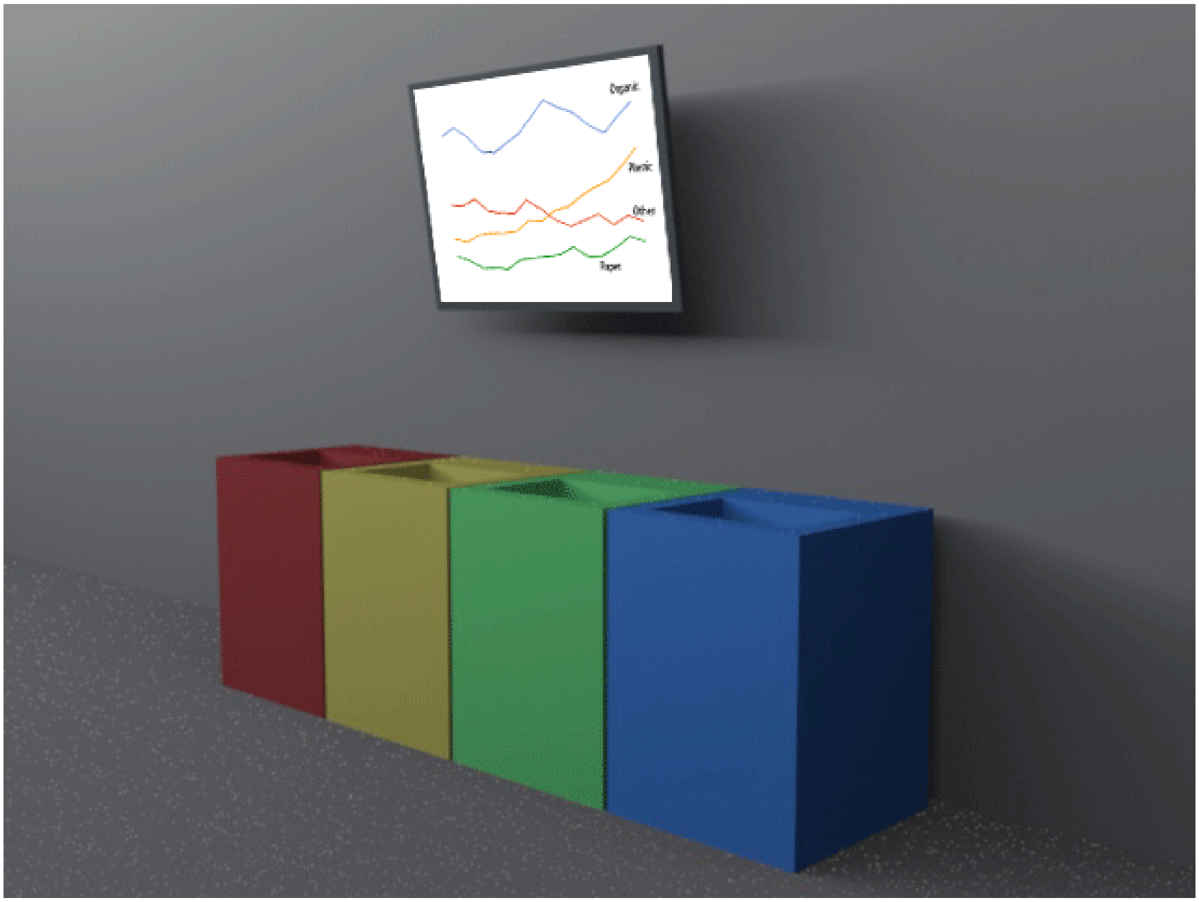

Figure 1. Perceived Waste Station Model

The purpose of this report is to assess the viability of implementing a waste station scale that gives instant feedback as waste is thrown away, and to give recommendations to the AMS on which products to use and which types of instant feedback are the most effective. These recommendations will be based on economic, social and environmental analyses of the different options. If the AMS decides to proceed with this project, waste stations can be constructed in the SUB, and then in other buildings if the project proves to be successful.

2.0 METHODOLOGY

A triple bottom line assessment is used to compare different options and ultimately determine the viability of the waste station scale project. The economic, social and environmental impacts of the project will be considered in order to provide a complete and well-rounded assessment. Our team consists of four members, so one member will be assigned to research and report on one aspect of the analysis, and the fourth will draw from the three aspects in order to integrate the research and reach a coherent conclusion.

The majority of our research comes from secondary resources such as journal articles, research papers, newspaper articles and books. We used many peer-reviewed academic journals and research papers in particular when researching the effects of using visual and other forms of feedback on sustainability. As a primary resource, we interviewed AMS New SUB Sustainability Coordinator Collyn Chan on November, 18 in order to acquire information about the goal of this waste station scale project as well as information and documents regarding the current practice of conducting waste audits.

The economic analysis of the project will consider the initial and operational costs of different types of scales in addition to other hardware costs. The total waste station costs will be compared with the alternative costs of conducting periodic waste audits in order to determine the economic viability of this project. The social and environmental aspects of the project are more difficult to assess, as effects of instant feedback may largely be dependent on the demographics. Journals and research papers will be used to compare and assess the effectiveness of different types of feedback on changing people's behaviour.

3.0 ECONOMIC ANALYSIS

To evaluate the economic impact of implementing a waste station scale system, we compared its design, build and maintenance costs with the alternative system of holding periodic waste audits on SUB waste production. We used information on a number of scale options, as well as estimated costs for a display and computer system in order to estimate the cost of implementing a single waste station. As a primary source, we interviewed AMS New SUB Sustainability Coordinator Collyn Chan for information about the new SUB, its sustainability practices and waste audits. In addition, Bruce Bowler, a sales representative from the local company The Scale Shop, was interviewed via telephone on November, 5th 2013 regarding the prices of scales and load cells.

3.1 Economic Indicators

The major economic indicator used is the cost of the waste scale system compared to the cost of conducting periodic waste audits. As the waste stations themselves are already going to be implemented, it is just the lifecycle costs of the scales, displays, computing hardware and software that must be considered. In particular, the equivalent uniform annual cost (EUAC)* of the options will be considered, as it provides a clear comparison between options that incur costs at different time periods (Newnan et al., 2009). The interest rate used in the EUAC calculations is 5%, and the two options will be considered over a 10-year period.

3.2 Scale Options

Two different scales will be considered: the Anyload FSP floor scale and a custom-built scale. Anyload is a company based in Burnaby, British Columbia, and it specializes in designing and manufacturing load cells and scales. Since it is a local company, the costs for shipping and maintenance will be lower, and the environmental impact will be lower. From our interview with Bruce Bowler, the Anyload scales will cost approximately $1000 each, and have an expected lifetime of 10 years.

Since there will be many waste stations, it may be viable to design a low-profile custom scale. Since Anyload is a local company and also manufactures load cells, their load cells will be considered. The Anyload 563YH load cell is compact and is proven to be usable in scale applications, as it is also the load cell used in the FSP scale mentioned above (Anyload, 2013). In addition to the load cell, metal is needed in order to construct a sturdy scale base and ramp, and some smaller electrical components are needed to construct a circuit so the load cell outputs can be read. Labour and design must also be considered in the cost, so the upfront cost of building a scale will be about the same as purchasing the Anyload scale.

3.3 Displays and Other Hardware

Hardware to go along with the scales includes a processor, a display monitor or small television screen and various electrical components needed to make the circuits that control the system. Although such design choices will ultimately be decided by the people implementing the project, the cost of a monitor can be estimated to be approximately $200 and, in the worst case scenario where a computer must be built to process the information, it will cost at most $500.

3.4 Software

The cost of the software includes the cost of designing a software suite to process the weight information and display the data on signage across UBC, as well as implementing some additional instant visual feedback techniques. Although it is difficult to estimate the cost of designing such a software suite, the complexity of the different feedback options is not that varied, as most of the differences are aesthetic.

One option to consider is adapting a similar project that is under way. According to Collyn Chan, the new SUB will contain signage that displays building data such as electricity and water usage and savings. If this project can be extended to interface with the waste station tracking system, it will likely be at a lower cost than designing a stand-alone software suite. Since the software will be designed by a professional firm, maintenance should not be needed as often, although it will still incur a cost. The advantage to using this option is that the signage will all be incorporated into a single software suite, although the cost is still largely undetermined.

Another option is to propose a student project to design the software suite to control the waste station system. The overall complexity of the software is not out of the scope of a university course, especially one at the fourth year level, so such a project can be designed and tested by students. In addition to this option being the least expensive, it promotes the new SUB's project goals of empowering and involving students (Alma Mater Society, 2010). The quality and reliability of a student-designed software suite is the major risk involved, and as such maintenance costs can range from being low to high.

3.5 Estimated Cost of Waste Station Tracking System

The new SUB will contain approximately 25 to 30 waste stations, but of these, only the high-traffic stations will contain the waste tracking system. As such, an estimate of 10 waste station tracking systems will be used to compute the cost. We will assume that five stations will have three streams and five will have four streams, meaning there will be 35 waste bins to be tracked and 10 complete display systems.

Adding together the costs of the hardware, the computing and display hardware will cost approximately $700 per waste station, and the scales will cost an estimated $1000 each. Therefore a three-stream waste station will cost approximately $3700 and a four-stream waste station will cost approximately $4700 up front. Maintenance is fairly inexpensive, and we estimate the processor and display to last five years and the scales to last 10 years. Given the number of waste stations indicated above, there will be a $7000 cost every five years and a $35000 cost every 10 years. As such, the EUAC at an interest rate of 5% and period of 10 years is computed to be $6150, meaning that it will cost approximately $6150 annually to implement and maintain such a system.

3.6 Estimated Cost of Periodic Waste Audits

According to Collyn Chan, the most recent waste audit conducted in 2011 cost approximately $50000. However, since the cost of a waste audit is related to the size of the building, it may cost up to $100000 to conduct a waste audit for the new SUB, which is 50% larger than the current one (Alma Mater Society, 2013). As such, if a waste audit is held every five years, the EUAC is computed to be approximately $23000 at an interest rate of 5%.

3.7 Comparison of Options

Comparing the EUAC of implementing the tracking system to holding periodic waste audits, the waste tracking system is estimated to be four times as cost-effective. Although many approximations were used in computing the cost of the waste tracking system, our estimation suggests that the tracking system is substantially more economic than holding waste audits. Although only the high-traffic areas of the new SUB are considered in our analysis, a small-scale prototype can be implemented to gauge the social and environmental impacts of the waste tracking system before a larger-scale implementation is considered.

In addition, the waste tracking system has the benefits of instant feedback and continuous data collection, compared to the waste audit, which only collects data for a small period of time, and also takes weeks to compute and publish the data. However, waste audits do produce more detailed data, such as more detailed classifications of waste. So while the waste scale system produces data more quickly and continuously, as well as at a fraction of the price as holding waste audits every five years, waste audits can produce more detailed data that is published in a formal report.

4.0 SOCIAL ANALYSIS

Main goals of this program is to increase awareness of sustainability, reduction of waste, awareness of different waste streams. Therefore the main social proponent that contribute to the output of UBC's waste production is the student body. Implementation of a visual feedback system has a large potential to affect the actions of the student body through real time monitor and display of waste statistics.

4.1 Feedback

Varying degrees of feedback effectiveness are illustrated by Lingard H et al. (2010) and Petersen, J. et al. (2007). This is exemplified by a Australian sports stadium construction site case study in which waste recycling is not affected but rather experience a jump in more efficient material usage measured by statistical significance. In this case study, goal setting was effective in prompting and reinforcing certain desirable actions by employees. Visual feedback programs deployed at 20 Ohio student dormitories enjoyed a drastic reduction in electricity usage by 32% versus water usage of 3%.

The main components for designing and implementing a feedback system involve determining system variables, modelling the system, selection and implementation of waste control methods, determining system sensitivity, determining goal setting strategy, and evaluating system post-implementation.

4.1.1 Determining of feedback variables

The selected waste stations will have scales to measure the waste mass according to different waste streams. Therefore, the main feedback variables are masses of waste collected for each waste stream. Since these scales are located at high traffic areas in the new SUB, the data from these stations will give a good approximation of the total waste in the new SUB. These calculations for waste production is also dependent on the time window selected. A shorter time window for waste calculation results in higher data fluctuation, whereas a longer time window results in lower data fluctuations, but a slower response to new data. Therefore a good selection would depend on overall system sensitivity.

4.1.2 Modelling feedback system

A feedback system is modelled in the following figure. The essential Waste Production Block models the actions of UBC student in regard to waste generation, which depends on a number of factors modelled as input to the block. The Goal Setting input serves as a plausible waste production value which is lower than the running system value. The auxiliary Waste Control Method blocks can be modelled as parallel blocks before Waste Production block. Ideally, Waste Control Methods should adapt to the difference between the set goal and measured values. The External Factors block models other inputs that may contribute to uncontrolled fluctuations in waste production, such as school holidays and different school seasons. The Waste Measurement block represents the scales used in data collection, and it is modelled in series and located before waste stream output. The Data Analysis block represents all the central data collection from scales and analysis of waste using a particular metric.

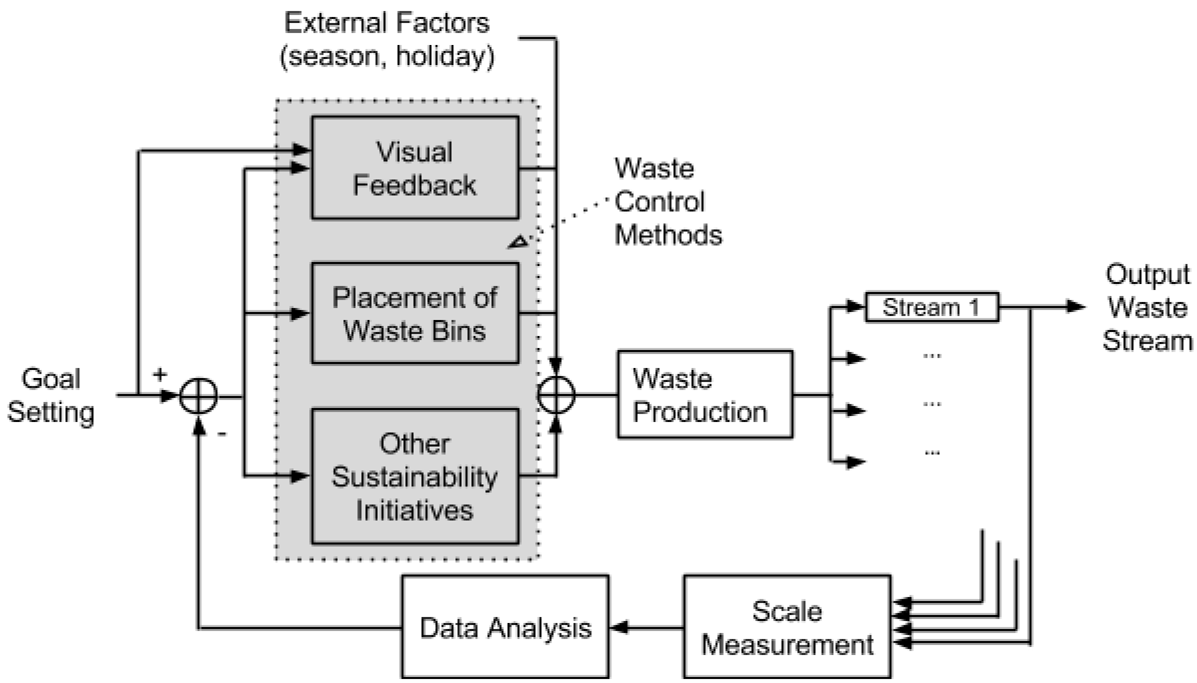

Figure 2. Waste stream feedback system model

4.1.3 Selecting and implementing waste control methods

Waste Control Methods are a collection of controllable methods that can be implemented by the student body and building operations as an effort to reduce waste output.

These might include:

- Determining optimal placement of waste bins
- Determining effective displayed visuals to the student body
- Creation and improvements of sustainability initiatives

4.1.4 Determining system sensitivity

An important aspect of implementing an effective system is to characterize its sensitivity response to a range of different combinations of inputs. For example, each different Waste Control Method impacts the overall system sensitivity as follows.

- Change in waste bin placement is likely to have fast system response
- Change in visual feedback is likely to have medium to slow rate of response
- Addition of sustainability initiatives is likely to have medium to slow rate of response

System sensitivities of different components should be taken into consideration when doing evaluating.

4.1.5 Determining a good goal setting strategy

There are many different strategies for creating a good goal-setting methodology. The main criterion for method evaluation is to consider goal achievability and use of effective impetus to increase moral of the student body in sustainability and waste reduction.

4.1.6 Evaluating system post-implementation

Critical evaluation of components of a feedback system lead to better a system. In our system, there exists External Factors which affect the amount of waste production. When evaluating the system, it is important to do in a way that takes into account these External Factors. Methods such as data categorization is able to differentiate data that might be affected by External Factors. For example, data might be categorized by weekdays, weekends, holidays, seasons and daily hours prior to applying data analysis. This way, results of data analysis used for reports and system evaluation can be interpreted in a more meaningful way. Furthermore, different Waste Control Methods have different response times. These components should be evaluated and monitored over a sensible time range prior to making constructive changes.

4.2 Visual Feedback

A specific type of waste control strategy is to use visual feedback on the student body. The goal of this type of strategy includes maximizing delivery of messages and concepts quickly and to any passerby as well as blending into ambient environment.

It is generally perceived that certain visuals such as pictograms are effective in illustrating simple concepts, however more complex processes are better communicated in verbal and written ways (Baghino A, 2013). Others suggest that use of visuals doesn't not necessary expand knowledge, but rather play an enhancing role through qualitative information (Cabrera A. et al., 2013).

Challenges for design and implementing a visual feedback involves selecting quantitative information to display, selecting method of visualization, reducing data for display, and evaluating system post-implementation.

4.2.1 Selecting quantitative information to display based on social impact

Data selection for reporting and displaying in a visual feedback system might be evaluated based on the following criterion:

- Meaningfulness, trend
- Fun factor
- Level of detail
- Comparative versus absolute

An ideal selection should cause the greatest social impact to the student body and result in maximum waste reduction. Different combinations of data types can be experimented to determine its social impact.

4.2.2 Selecting Visualization method

It is important to select an effective method to communicate to the student body. Various types of visualization techniques exist. Our dataset is in the form of a time series, it is natural to use a form of visualization that presents quantities over a given time span. As mentioned earlier, visualizations might be used to communicate different levels of detail, comparative quantities, general trends, and fun factor.

Table 1. Suggested Criteria for Visual Data Selection

Criteria	**Visualization Technique**
Trends	simplified pictogram/plots
Attention Grabbing	animated plot, themed graphics, regular update
Level of detail	multiple categorized plots, different time span
Comparative vs Absolute	comparative data plots

4.2.3 Reducing Data

Due to inherent external factors which might introduce noise and unmeaningful data fluctuations, it is ideal to eliminate these affected data in the Data Analysis stage through methods such as data categorization and filtering. In addition, huge data sets should be regularly discarded or reduced to a reasonable size and resolution due to practical constraints of data transmission, data storage, and data interpretation.

4.2.4 Evaluating Visual Feedback Post-Implementation

Evaluation and improvement to visual feedback system might done using experiments in which different combinations of visualizations are used and date is collected and analyzed for its impact on amount of waste generation. A direct approach to evaluate social impact is to survey the student body on preferences of visualization and awareness of current visual feedback.

As mentioned earlier, there might exists a time lag between new feedback modification and its measurable impact on the student body and the amount of waste generation. In addition, background data noise and trends may overwhelm any noticeable impact of feedback modification, so we have to take this into consideration before making any useful conclusion.

5.0 ENVIRONMENTAL ANALYSIS

The environmental impact of the waste station scale must be analyzed and compared with the current waste tracking system to find the more sustainable option for the new SUB. The materials used to create these waste station scales, energy consumed, life-cycle and amount of waste created will be taken into consideration.

5.1 Waste Station Materials

The main components of the new waste station will be a scale with a load cell, display monitor, and the casing around the waste station. The scale requires a steel base, with an estimated size of 600 mm x 600 mm x 5 mm. The amount of steel used will be approximately 14.0 kg. The load cell is mostly created with alloy steel with advanced electronics attached to it. The size of a 563YH load cell is 31.8 mm x 130 mm x 31.8 mm; the amount of alloy steel used will be 131.5 mm^3 and weigh approximately 1.1 kg (Anyload, 2013). The amount of copper and plastics used in the electronics is negligible. The monitors of the new waste station need mercury, semiconductors, and inert gases to be produced.

The process needed to produce monitors create large amounts of wastewater that is concentrated in phosphoric acid, however Toshiba has stated they reuse this water as a raw material for fertilizer (Toshiba Corporation, 2013). The new waste station will not increase in size, as a scale is just being implemented. The net environmental impact of creating the case for the waste station compared to the current waste stations will be zero. The CO_2 emitted by the production of total 15.1 kg of steel is 24.7 kg, while the energy consumed to produce 15.1 kg of steel is about 111.8 MJ (World Steel Association, 2013). The CO_2 emitted by the production of a LCD monitor is approximately 250 kg

(Stutz, 2013). The energy consumed in production is about 278 MJ (Environmental Protection Agency [EPA], 2013).

5.2 Transportation

The load cells being implemented into the new stations are produced by Anyload, a local business in Burnaby, BC. The approximate delivery distance from Anyload to UBC is 25 km, and assuming energy consumption of 2.4MJ/km there will be 60 MJ of energy consumed by transportation, and assuming emissions of 176g CO_2/km there is are CO_2 emissions of 4.4kg per transport (Martinuk, 2010).

5.3 Use

The load cells will be on all the time in order to track the waste deposited in the different streams. The monitors will also be on all the time to have real-time assessments of how much waste is being recycled and how much of an impact an individual is making by putting their waste in separate streams. The load cell energy consumption should be minimal, as they do not require much energy to run. The majority of energy use will be from the monitors displaying data. The monitor, when on for 24 hours a day, will consume approximately 4.3MJ of energy per day, and emit approximately 1600 kg of CO_2 per year (Carbon Footprint Ltd., 2013).

5.4 Disposal

The recycling of steel is very efficient, because steel is used as raw scrap material to create more steel the recycling of steel will be negligible. The disposal of a television monitor however will have a larger impact on the environment. In Canada, a lot of e-waste is recycled, however most of it will be left in landfills or e-waste will be exported due to the much lower cost than recycling (Public Works and

Government Services Canada, 2013).

5.5 Summary

A summary of the CO_2 emissions and energy consumption for the life cycle of the waste station is given below.

Table 2. CO_2 and Energy Consumption for 1 Waste Station

	CO_2 (kg)	**Energy Consumption (MJ)**
Materials	274.7	389.9
Transportation	4.4	60
Use	1600 (per year)	1569 (per year)
Disposal	50	100
Total	1929	2119

The table shows the CO_2 and energy consumption usage for one year, however all the other figures are only used once. The totals must be multiplied by however many waste stations are given, assuming a total of 10 new waste stations will be created, the total CO_2 and energy consumption will be 19290 kg of CO_2 and 21190 MJ of energy. This amount of energy and CO_2 should be offset by how many students will be using these new waste stations. It is assumed that 50,000 people will be using the new SUB everyday. This will make the energy consumption and CO_2 emissions per person to be very small.

6.0 CONCLUSION AND RECOMMENDATIONS

The triple bottom line analysis concludes that it is viable to implement the waste tracking system in the new SUB. Economically, the system will be almost four times cheaper to implement and maintain than the alternative of conducting waste audits every five years. The social analysis shows that visual feedback is an effective way to guide people to make more sustainable choices, although different forms of feedback will have varying degrees of effectiveness. From an environmental standpoint, implementing the waste tracking system is not as viable as holding waste audits. However, if the CO_2 produced and energy required is averaged over the number of people who use the SUB, the impact is much smaller. Also, the environmental impact ultimately depends on the reduction in waste produced by students and faculty as a result of implementing this system.

It is important to take into consideration the time that it will take for the statistics to take form. If the waste tracking system is implemented, and data is collected over a long period of time, the statistics and ultimately the feedback will become more impactful. In addition, the educational value and the use for the data is not limited to just telling people to produce less waste. The data can show trends in waste production, as well as guide the AMS to improve the sustainability of the new SUB. As such, it is recommended that a pilot project be initiated to test out the waste tracking system on a small scale. In addition, the pilot project can assess the effectiveness of certain visual feedback techniques, and ultimately be tailored to suit the demographics of UBC.

REFERENCES

Alma Mater Society. (2010). *The Project.* Retrieved November 14, 2013 from: http://mynewsub.com/site/?page_id=9.

Anyload. (2013). [Datasheet] *563YH Single Ended Beams.* Retrieved November 19, 2013 from: http://www.anyload.ca/Individual%20pages/563YH.pdf.

Baghino A. (2013). Icons of Complexity. *2CO Communicating Complexity: 2013 Conference Proceedings*, 33-41.

Bowler, B. (5 November 2013). Telephone Call.

Cabrera A., de Dios A., & Rodilla R. (2013). Infographics as a Tool to Interpret Reality. *2CO Communicating Complexity: 2013 Conference Proceedings*, 42-48.

Carbon Footprint Ltd. (2013). *Household Energy Consumption.* Retrieved November 20, 2013 from: http://www.carbonfootprint.com/energyconsumption.html

Chan, C. (18 November 2013). Interview.

Environmental Expert (n.d.). Waste Streams Software. *Environmental Expert*. Retrieved Oct. 23, 2013, from http://www.environmental-expert.com/waste-recycling/waste-streams/software.

EPA. (2013). *Summary and Conclusions.* Desktop Computer Displays A Life-Cycle Assessment. Retrieved November 5, 2013 from: http://www.epa.gov/dfe/pubs/comp-dic/lca/Ch5.pdf.

Lingard H., Gilbert G. & Graham P. (2010). Improving Solid Waste Reduction and Recycling Performance Using Goal Setting and Feedback. *Construction Management and Economics*, 19(8), 809-817.

Martinuk, M. (2010). *Energy Use in Cars 5: Gasoline Cars vs. Electric Cars.* Retrieved November 9, 2013 from: http://c21.phas.ubc.ca/article/energy-use-cars-5-gasoline-cars-vs-electric-cars

Newnan, D. G., Whittaker, J., Eschenbach, T. G. & Lavelle, J. P. (2009). *Engineering Economic Analysis* (2nd Canadian ed.). Oxford University Press.

Petersen, J. E., Shunturov, V., Janda, K., Platt, G. & Weinberger, K. (2007). Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives, *International Journal of Sustainability in Higher Education*, 8(1), 16-33.

Practice Greenhealth (n.d.). Waste Tools & Resources. *Practice Greenhealth*. Retrieved Oct. 23, 2013, from https://practicegreenhealth.org/topics/waste/waste-tools-resources

Public Works and Government Services Canada (2013). *Federal Electronic Waste Strategy.* Retrieved November 25, 2013 from: http://www.tpsgc-pwgsc.gc.ca/ecologisation-greening/documents/dechets-waste/dechets-waste-eng.pdf.

Rodgers, J. & Bartram, L. (2011). Exploring Ambient and Artistic Visualization for Residential Energy Use Feedback, *IEEE Transactions on Visualization and Computer Graphics*, 17(12), 2489-2497.

Stutz, M. (2013). *Carbon Footprint of a Typical 19" Business Monitor From Dell.* Retrieved November 15, 2013 from: http://i.dell.com/sites/doccontent/corporate/corp-comm/en/Documents/display-white-paper.pdf

Tanskanen, J. H., Reinikainen, A. & Melanen, M. (1998). Waste streams, costs and emissions in municipal solid waste management: a case study from Finland, *Waste Management Research*, 16(6), 503-513.

Taylor, R., Rutledge, D. T., & van Roon, H. (2011). Building Capacity in Urban Sustainability Assessment through Use of a Scenarios Game, *Journal of Education for Sustainable Development*, 5(1), 75-87.

Toshiba Corporation. (2013). *Efficient Use of Resources: Reducing the Total Waste Volume.* Retrieved November 19, 2013 from: http://www.toshiba.co.jp/env/en/industry/waste.html

World Steel Association (2013). *Steel's Contribution to a Low Carbon Future.* Retrieved November 9, 2013 from: http://www.worldsteel.org/publications/position-papers/Steel-s-contribution-to-a-low-carbon-f uture.html

Unnisa, S. A. & Rev, S. B. (Eds.). (2012). *Sustainable solid waste management*. Point Pleasant, NJ: Apple Academic Press.

APPENDIX I. ANNOTATED BIBLIOGRAPHY

Baghino A. (2013). Icons of Complexity. *2CO Communicating Complexity: 2013 Conference Proceedings*, 33-41.

This article argues that communication of certain concept, especially non-verbal ones, is better done using pictograms to enhance understanding. Example pictograms are illustrated in the article. Pictograms can potentially be incorporated into the e-signage system. The article is peer reviewed since it is published for a conference.

Cabrera A., de Dios A., & Rodilla R. (2013). Infographics as a Tool to Interpret Reality. *2CO Communicating Complexity: 2013 Conference Proceedings*, 42-48.

This articles tries to tie together quantitative and qualitative elements of analysis by providing an additional emotional aspect to different types of audience. It explores techniques to extract stories and also use of different types of visual representations. Ideas from this article can be employed in e-signage visualization. This literature article is peer reviewed since it is published for a conference.

Environmental Expert (n.d.). Waste Streams Software. *Environmental Expert*. Retrieved Oct. 23, 2013, from http://www.environmental-expert.com/waste-recycling/waste-streams/software.

This website page provides a list of commercial available software for waste stream tracking. We can further inquire information about each system and decide whether or not if there is any suitable software to use for our waste tracking system. This web site comes from an independent company that provides a platform for business to business marketing related to environmental products.

Lingard H., Gilbert G. & Graham P. (2010). Improving Solid Waste Reduction and Recycling Performance Using Goal Setting and Feedback. *Construction Management and Economics*, 19(8), 809-817.

This article seeks out the effectiveness of using goal setting and feedback on waste manage by performance an experiment on a sports stadium construction site. Evaluation reveals improvement on waste disposal volume and more efficient material usage. This type of approach can be integrated into our waste stream tracking system. This article comes from a journal which is peer reviewed.

Petersen, J. E., Shunturov, V., Janda, K., Platt, G. & Weinberger, K. (2007). Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives, *International Journal of Sustainability in Higher Education*, 8(1), 16-33.

This paper looks at the effects of visual feedback and incentives on students' use of electricity and water. Students who received visual feedback were shown to use 32 per cent less electricity and 3 per cent less water than students who did not receive feedback. This paper is based on a study done at 22 post-secondary residences, by a group of environmental studies researchers. Although the study does not consider waste production, it shows that visual feedback does affect people's behaviour.

Practice Greenhealth (n.d.). Waste Tools & Resources. *Practice Greenhealth*. Retrieved Oct. 23, 2013, from https://practicegreenhealth.org/topics/waste/waste-tools-resources

This website page provided external links to tools and resources regarding waste management tracking systems and waste reduction organizations that are presently available. This web page comes from a non profit organization promoting and supporting green practices.

Rodgers, J. & Bartram, L. (2011). Exploring Ambient and Artistic Visualization for Residential Energy Use Feedback, *IEEE Transactions on Visualization and Computer Graphics*, 17(12), 2489-2497.

This paper focuses on the effect of visual feedback regarding energy usage in households using ambient images. It is shown that it is viable to implement these types of visual feedback, but special care needs to be taken so that the imagery is visually appealing and informative at the same time. The authors are both IEEE members, so they are aware of engineering practices and are in the same field of study as us. In addition, the paper is well constructed and offers some insight into the requirements of the imagery in a system based on visual feedback.

Tanskanen, J. H., Reinikainen, A. & Melanen, M. (1998). Waste streams, costs and emissions in municipal solid waste management: a case study from Finland, *Waste Management Research*, 16(6), 503-513.

This paper looks at the amounts of the different types of waste streams produced by municipalities in Finland, although the focus is on how much of that waste can be recovered and the costs of it. The authors all work at the Finnish Environment Institute, so this paper is credible. Although the waste scale is only meant to measure the amount of waste produced in the SUB, this paper gives us a scope of what work has already been done in regards to waste management, and some of the effects that waste production has environmentally and economically.

Taylor, R., Rutledge, D. T., & van Roon, H. (2011). Building Capacity in Urban Sustainability Assessment through Use of a Scenarios Game, *Journal of Education for Sustainable Development*, 5(1), 75-87.

This paper discusses the effects of visual feedback from playing a simulation game based on sustainability scenarios in a futuristic setting. The results show that the people who played the game were more engaged in thinking about sustainability. The study is not that relevant to our project, but the idea of user interaction in the form of a game and the positive effects that it can have on sustainability can be considered when we look at software components.

Unnisa, S. A. & Rev, S. B. (Eds.). (2012). *Sustainable solid waste management*. Point Pleasant, NJ: Apple Academic Press.

This book looks at some of the different methods of solid waste stream management, with a focus on sustainability. Overall, a number of different methods are discussed and compared. The chapters are written by experts in their specific fields, so the book contains credible and objective information. Although our task is not to manage the waste produced by the SUB, this

book contains valuable background information as to ways waste can be managed.