Identifying Opportunities for Enhanced E-waste Management in Canadian Post-Secondary Institutions

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Abstract

Effective e-waste management strategies are one of the most important challenges societies will have to overcome to meet the overwhelming increase of end-of-life electronics. E-waste management at the post-secondary scale in Canada is severely lacking in public availability of information and diversity of strategies. This inquiry explores the current practices and quantitative successes of Canadian post-secondaries in management of their e-waste and proposes the potential for further expansion of such programs. Multiple sources of information were consulted including a literature review on a wide range of Canadian schools and a smaller case study of e-waste management at McMaster University, which included secondary data usage of two research teams from the university on e-waste perceptions and experiences. Two patterns were recognized, there is little consistency between the innovative e-waste management strategies of different institutions and there is under-researched potential on campuses to strive for greater e-waste reuse. From these challenges, an e-waste management framework was created. This involved producing a six step approach institutions could use to begin to expand their commitment to improving their e-waste management. Further research should be conducted to observe the framework's effectiveness put in action. Additionally, other institutions should challenge and expand this framework to advance its impact.

Introduction

E-waste is the general term used to identify end of life electronic materials (Perkins, 2014). Unlike other forms of waste, this stream of garbage is rapidly evolving with the technological boom of recent decades. Although the exact number of electronic devices currently circulating is impossible to quantify with certainty, it was estimated in 2020 that there were over 4.66 billion unique internet users around the world (Kemp, 2020). Under the assumption that each of these users access the internet from an electronic device, over half the world owns some form of electronics that will at some point become obsolete and abandoned. The rapid generation of e-waste is becoming a global problem as countries scramble to put policies in place to manage their share.

In Canada, at a federal scale there are currently no policies in place to regulate ethical e-waste management (Lepawsky, 2012). This is concerning, considering the magnitude of the problem and resulting lack of consistency between provinces (Portugaise, 2023). In a 2016 study from the University of British Columbia, it was estimated that Canada produces over 725,000 tonnes of e-waste annually, of which only 20% is ethically recycled (Kumar, 2016). On a provincial scale, Ontario has ambitious policies in place to manage e-waste. The province issued regulation 522/20 in September of 2020 to place more responsibility on electronics producers to care about the complete lifecycle of their products (Vitello, 2022; Sphera EC4P, 2020). This included being responsible for setting up a collection point for e-waste drop off under their own management, reporting the annual quantity of material processed, and becoming registered with

the provincial authority. Most notably the targets for e-waste collection were set at 55% of annual electronics supplied and increased incrementally by 5% to peak at 70% collected by 2025 (Sawicki, 2022). Due to the recent adoption of this policy, there has been little public reporting on the efficacy of these targets (Portugaise, 2023). Furthermore, the policy specifies that had targets not been met, "best efforts" practice must be provable into attempting to meet targets. Best efforts practices are not well defined in the regulation and may hinder the necessary responsibility of the producer. In addition, organizations like the Ontario Waste Management Association fear the regulation actually undercuts current recycling processing amounts by almost 50% (Ontario Waste Management Association, 2021). Finally, the regulation does little to promote reuse and the right for consumers to be able to repair a producer's product, which is a missed opportunity when compared to other international regulations (Sawicki, 2022; Portugaise, 2023). Less stringent policy allows for undercutting and lack of innovation in e-waste management strategies.

The inspiration for this inquiry was exploring e-waste management potential further while constraining its sheer magnitude of scope to that of post-secondary institutions in Canada. Post-secondaries are uniquely situated in their status and potential to promote change. Post-secondaries balance the dichotomy of being well-funded public institutions and prestigious places of work while hosting diverse mixed income students who populate the majority of a campus. Canadian post-secondaries also create communities that are highly receptive to new initiatives and programs because they are small, controlled environments, and full of engaged stakeholders (Rehman, 2022). As personal electronics become a necessary tool for research and learning, electronic waste is abundant in post-secondary institutions. This inquiry explores e-waste management at the post-secondary scale and serves as a framework for future potential e-waste management strategies in these institutions as well as expansion into legislation.

Central Question

What are the current practices of Canadian post-secondary institutions in management of their e-waste and how might information sharing expand these practices?

Background and Study Context

As a student who is highly invested in e-waste management at McMaster it was important for me to explore the history of tech collection, reuse, and recycling efforts at my university. I have been involved in McMaster's e-waste for the past two years, however the history of e-waste management has much older roots. McMaster hosts a variety of public documents and articles available to demonstrate its commitment to reporting on its expansive electronic waste reuse, sustainability, and recycling initiatives. These are highlighted in McMaster's Academic Sustainability Program Office's annual reports (McMaster Academic Sustainability Programs, 2022). The university has been collecting and recycling e-waste since the first E-waste Collection, Reuse, and Recycle event for Earth Day in 2009 (McMaster University ASP Office,

2009). McMaster's program evolved in 2018/19 with the Trash to Treasure initiative that would see electronics refurbished and donated where possible, prior to recycling. In Trash to Treasure's first year of operation, the program was able to donate 70 devices to local children in need and upcycle 1000 kg of tech to students (McMaster University ASP Office, 2019). Following a period of dormancy during the covid-19 pandemic, in 2021 McMaster supported the reboot and redevelopment of Trash to Treasure into the ACCESS Tech program. This large-scale student-led initiative focused on donating great condition end-of-life electronics to a local partnered non-profit, Empowerment Squared, and offering up remaining items to students. This was achieved through hosting numerous community donation and reuse events throughout the term and delivered great results. Since then, the program continues to work well and has donated almost 200 more devices to partnered non-profit, Empowerment Squared. Furthermore, ACCESS Tech upcycled over 2000 kgs within the university community (McMaster University ASP Office, 2022).

In addition to the history above, my involvement with ACCESS Tech allows for in-depth insight into the program's operation pattern to achieving its success. The ACCESS Tech program runs a cyclic pattern of e-waste donation, reuse, and recycling efforts. As can be seen in Figure 1, the program's last resort strategy is recycling. This contrasts with what was observed in the literature review of legislation efforts and observation of many other Canadian institutions. Most schools focus on recycling as their primary method of managing e-waste. McMaster is shifting to follow the three R's as "reduce, reuse, and then recycle" aiming to achieve a more circular economy (Wilcox, 2022). The ACCESS Tech cycle begins with an e-waste collection event. These collection events are a day for the university community to bring in any electronic donations to the program, they occur twice a year. Collection events are communicated throughout various platforms (email, social media, etc.) in advance to encourage the university community awareness and engagement. After the collection, a core team of four students, who are part-time student staff jointly employed by McMaster's Facility Services and University Technology Services, begin sorting the e-waste. Upwards of 100 items are commonly received and processed per collection event. As part of sorting, e-waste is individually categorized in ACCESS Tech's permanent office space on campus. High quality, newer items are refurbished to be donated to partnered local non-profit, Empowerment Squared. Deliveries are made approximately once every four months and are organized as items are prepared to ensure a consistent stream of processing donations. Older items are cleaned, wiped of their data, and brought to student reuse events, which happen soon after sorting. Reuse events are hosted in popular student spaces and advertised through partnerships with many of the campus's student groups. These events have seen attendance of over 200 upcyclers, which equate to reuse amounts of around half a ton of e-waste. After a reuse event has ended, any remaining items are recycled in e-waste bins that same day with partnered third party recycler, Greentec. Greentec is a trusted ethical recycler and is certified under Responsible Recycling (R2) certified by Sustainable Electronics Recycling International (SERI) (SERI, 2021). This final step of recycling ensures the office is cleared and prepared for the next collection event to come. The cycle then begins again with a new collection event. Approximately two full cycles can be completed per school year (one cycle every four months), with additional reuse events and donations occurring if a surplus of items is available.

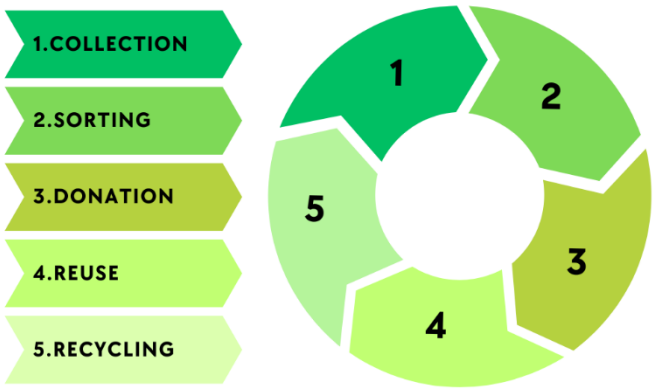

Figure 1: ACCESS Tech's Cyclic Operation Strategy

Methods

This inquiry aimed to explore the current practices and quantitative successes of many Canadian post-secondaries in management of their e-waste and offer the potential for further expansion of such programs. A comprehensive literature review was conducted based on the Association for the Advancement of Sustainability in Higher Education (AASHE). The AASHE evaluates the self-reported sustainability reports of worldwide post-secondary institutions on the Sustainability Tracking Assessment and Rating System (STARS) website ("STARS Participants & Reports", 2023). STARS aims to serve as a unified hub for comprehensive sustainability information on North American post-secondaries, allowing for a common measurement between institutions. These reports ranged in the dates they were submitted from 2022 to 2016 and were ranked by AASHE on the efficacy of the institution's overall sustainability effort from a four-point scale of Bronze to Platinum. The most recently submitted report was utilized in this compilation of data. Pertinent sections examining the e-waste management of an institution from the STARs reports were the "Waste Diversion" & "Hazardous Waste Management" sections (AASHE, 2022).

The three post-secondary institutions with the largest quantitative recycling and reuse reported on by STARS were deemed to host the most involved recycling and reuse strategies. Upon recognizing the shortcomings in the reporting of these strategies on STARS, these three schools were then explored with additional research. This included a deep dive into their personal institutional websites and any publicly available articles to examine their operation at achieving best practices. The results of the exploration of STARS can be found below under "Literature Review".

In order to provide a glimpse into a smaller geographic scope and offer information about the post-secondary institution most familiar to me, research from McMaster University was examined further. Although McMaster has not submitted a STARs report in the past, as the home

of this inquiry report, its e-waste management is extremely familiar to me. This year the Sustainability programs office engaged two student groups to conduct qualitative research into aspects of the ACCESS Tech program. The two studies completed were exploring “Student experiences of 'upcycling' IT from ACCESS Tech at McMaster" as well as "Donor experiences of donating IT to ACCESS Tech at McMaster" (**forthcoming**). These two groups, both from the 4S06 sustainability course (*SUSTAIN 4S06: Leadership in Sustainability*), collected 41 sample participant interviews total with a series of predetermined questions (see Appendix A for these questions) aimed at better understanding and innovating the ACCESS Tech program for the future. Each research team interviewed participants at their respective events. For the purposes of this inquiry these two sets of anonymous transcribed interviews were analyzed as secondary usage of data. This data was approved for further analysis in this inquiry by the McMaster Research Ethics Board (Project ID: 6378). Key themes and patterns were analyzed by exploring select interview questions as can be seen in Table 1. These questions were chosen and explored further in quantitative analysis. This exploration offered insight into opportunities and barriers to starting up such programs in other institutions. Findings of each of these questions are presented in the results section below under “Study”.

Table 1: Key Interview Questions assessed for Quantitative patterns

Upcylcers Reuse Success Rate: Is there something you were looking for? Did you find it?
Upcyclers Reuse Need: What are you planning to do with these items?
Donor Demographic: What brought you to donate your tech today?
Donor Frequency: Is this your first time donating your used tech?
Donation Types: What items are you donating today? Vs **Upcycler Wants:** Is there something you were looking for? Did you find it?

Limitations and Bias

It is important to comment on my personal biases associated with wanting to invest in the study of post-secondary e-waste management. My personal background includes being introduced to the initiative as part of McMaster’s 3S03 course (Implementing Sustainable Change) during which I helped organize and volunteer at events as well as working for the ACCESS Tech initiative since January of 2021. This part-time employment involves directly working with management of campus e-waste as well as the opportunity to further innovate the program to increase the amount of e-waste being reused by multiple target groups in the McMaster community. Two major potential sources of bias arise through this involvement, confirmation bias and the Dunning-Kruger effect. Through personal experiences working with e-waste and having previous background knowledge, it is important not to equate prior knowledge from one institution to that of every other post-secondary institution in Canada. One must not

confirm beliefs rather than produce an impartial assessment of facts. Although my personal background would suggest some level of knowledge on the topic of e-waste management, I am by no means an expert, nor should I claim to be. Expert research papers will be consulted to support the literature review and all new idea generation will be done with review of other sustainability experts, supervisors, and fellow peers. However, I also recognize that a limitation of my personal involvement with e-waste management is that I will need to base my evaluation of other schools on what's publicly available, whereas I can offer supplementary evaluation of McMaster from personal experience and conversations with my connections. I want to be fully transparent of this additional information available to me and hope to still deliver interesting discussion based on the entire landscape of post-secondary Canadian e-waste management.

Finally, optimism bias is a newly discovered predisposition that may also apply. In my personal desire to improve the overall management of ethical Canadian e-waste disposal, the shortcomings of certain findings must not be overlooked in order to only highlight potential positives. Overbearing optimism must be avoided by equally considering both barriers and opportunities and treating barriers as important to highlight to reach an overall net positive rather than hidden and avoided.

Scope of Results

The key findings of the literature review and research themes are not representative of the entire breadth of Canadian post-secondary e-waste. The STARs database of reports was the only source of information for e-waste management of all post-secondaries considered. This was due to the time constraints of the project and consistency of reporting between institutions that STARs offer. Individually researching each of the 96 schools in Canada was not in the scope of this inquiry.

Furthermore, the interview data examined as a case study at McMaster only represents the voices of 41 people from a single campus. This data set also included students and staff who were already somewhat interested in sustainable e-waste management. Although this research study offered interesting results and was a very large data set for qualitative research, it is important to recognize the need for future research assessments at other institutions. In my personal recommendation conducting interviews at other institutions on e-waste management would be a great next step at capturing more quantitative data.

Results

Literature Review

Upon completion of the STARS data review, 97 post-secondary institutions were identified within Canada. From these 97 schools, 55 institutions submitted a STARS report with report sections of interest and were included in the comprehensive table of reported amounts of recycling and reuse as seen in Appendix B. The remaining 44 schools without STARS reports are listed in Appendix C and were deemed out of the scope for this inquiry. Examining the

electronic waste amounts recorded by post-secondaries from their STARS reports, very few schools recorded or participated in recording of any reuse data. STARS does not provide a section to directly report on the amount of e-waste recycled or reused, this number is combined with all other material. Therefore, the value estimated as a fraction of the potential e-waste reused was represented by the "Materials intended for disposal but subsequently recovered and reused on campus, performance year" category of data of which only 12 schools out of 55 provided. Of these schools, three reported no reused material intended for waste, four schools reported less than five tons of total weight reused, and five schools reported over 20 tons of reused material. This data can be summarized in Appendix B. From these results it was crucial to further assess the key reuse strategies deployed by the top three universities with largest reported quantitative reuse: Carleton University, University of Alberta, and Wilfrid Laurier University.

Carleton University has partnered with its own third-party recyclers, Electrobac and CCS Hardware to provide ethical electronics recycling on campus (Mansfield, 2022). One building on its campus collects all the electronic waste to be provided to the recyclers. Additionally, three secure e-waste bins are located on campus for smaller sized electronics to be dropped off by the community (Carleton, 2020). Although no reuse strategies were found during research, the university has hosted a great lecture series promoting "Reuse of Waste Electrical and Electronic Equipment (WEEE)" as best practice for such material. It's important to consider that Carleton acknowledges its current e-waste strategies as not being perfect and highlights steps to achieve better future programs (Carleton, 2021).

University of Alberta works with their campus' Supply management services (SMS) to collect all e-waste material together and then send it off to a recycling center through a third party. Items are collected through submitting a service request or periodically collected from five e-waste bin locations throughout campus. From their STARs report section OP-20, "Electronic Waste Recycling Program" their method of recycling by third party specifies that any items sent from the university are confirmed to be destroyed with a "record of destruction" (Dietrich, 2012). This indicates electronic items are most likely fully disassembled for their raw material components rather than attempted to be preserved and upcycled whole (University of Alberta, 2019). The university of Alberta has posted a thorough 10 year "Zero Waste Plan" with the short-term goal of partnering with new electronics recyclers with e-stewards or responsible recycling certification (University of Alberta, 2021). E-stewards is the North American certification for ensuring accreditation for recyclers focused on best practices regarding safe, ethical, and efficient e-waste management (e-Stewards, 2019). Finally, an event posting for "E-waste round- up" was found to encourage the university community to bring in all their obsolete electronics together and promote recycling and reuse of these items. However, no similar events have been publicly posted since 2008 so follow up would be recommended (University of Alberta, 2008).

Laurier University shares some unique initiatives and opportunities to reuse electronic waste on campus because they host a "Free Store" on their campus where electronics are accepted as donations to be upcycled (Wilfrid Laurier University, 2021). This is a permanent space on campus that encourages students and staff to donate any items no longer of use to be

given out to those who need it free of charge. The university partners with third party recycler, Greentec, to ethically collect and recycle as much of its electronic waste as possible (Schwarz, 2019). Similarly to the University of Alberta, the Greentec recycling company does not promote reuse so much as disassembly of raw material and destruction of personal data. Finally, Wilfrid Laurier University created an innovative new e-waste bin design. This project was championed by two students calling their creation the "Convenience Bin" which combines the collection of batteries, light bulbs, and smaller mobile devices into one convenient bin location, see Figure 2. As of 2022 although only one such bin has been installed, the student team hopes to install many more within the coming years and inspire other schools to adopt the innovative bin design as well (Winslow, 2022; Ghonaim, 2022).

Figure 2: Laurier Student Reena Sakran sits next to the new "Convenience bin" (Winslow, 2022)

From exploring the top three institutions more in depth on their own websites, I was pleasantly surprised at the amount of additional information available. Each of Carleton, University of Alberta, and Wilfrid Laurier University hosted innovative strategies that other schools could learn from. However, these inspiring methods for reuse or recycling were not found because of the STARS database but rather from searching further into the school's own platforms. This led me to the conclusion that STARS is lacking significantly in its e-waste management reporting. If I had never thought to explore institutions more thoroughly, I would have assumed the overall outlook on Canadian post-secondary e-waste management was very bleak. The format of the STARS reports does not offer enough room to be able to challenge institutions to share all their current strategies. Overall, there are only four general prompts to allow an institution to share its e-waste management (see Table 2). From these guiding questions, three prompts strictly require a yes or no answer while the final prompt encourages a brief description of the programs available. Therefore, although STARS is extremely beneficial in offering a standardized method of self-reporting for all institutions, in order to improve e-waste management information sharing, significant reform should be done to its reporting

requirements. I would recommend STARS offer new prompts asking specifically about e-waste reuse, recycling, and reduction strategies.

Table 2: List of Stars Prompts related to discussion of e-waste management

1. Does the institution have or participate in a program to responsibly recycle, reuse, and/or refurbish electronic waste generated by the institution?
2. Does the institution have or participate in a program to responsibly recycle, reuse, and/or refurbish electronic waste generated by students?
3. A brief description of the electronic waste recycling program(s), including information about how electronic waste generated by the institution and/or students is recycled
4. Is the institution's electronic waste recycler certified under the e-Stewards and/or Responsible Recycling (R2) standards?

Furthermore, although out of the scope of this inquiry, it would be extremely important to conduct future research to explore more Canadian post-secondaries on their own websites regardless of the STARS quantitative rankings. Then to take it a step further, follow up with in-person interviews of sustainability professionals at each institution to understand their programs and best practices more in-depth. Similarly, to how I was able to offer more information on ACCESS Tech's process at McMaster that isn't widely published online, I believe searching to get institutional knowledge that is not publicly available from experts is an amazing next step.

McMaster Study

Two surveys were conducted with two unique demographics of electronic waste users on campus, student upcyclers and donors of e-waste material. Key patterns were examined to demonstrate opportunities for university e-waste management innovation. From examining the student upcycling event, which was attended by over 300 undergraduate students, 17 of the 21 participants interviewed (81%) took an item home with them, see Figure 3. This demonstrates that these reuse events are not only popular for the viewing of old and often socially described as "obsolete" electronics but rather that a larger majority of students attend them to take something home. Furthermore, 13 of the 21 students surveyed (62%) planned on using the items they took home for school use and co-op work rather than simply personal use. This means that electronics the school no longer needs for its staff can go directly back to its students to be used for work within the institution itself, a great circular relationship.

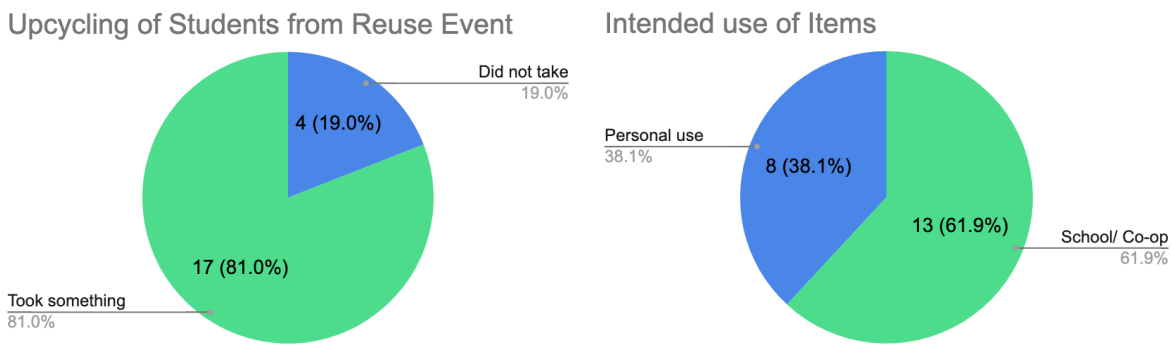

Figure 3: Upcycling of Students from the ACCESS Tech Reuse Event (Left) and Intended use of these Items (Right).

The data at the donation event highlights that there are many donors on campus within both student and staff demographics. From Figure 4, donations from staff and students totaled 65% and 35% respectively. There was also a wide variety of types of electronics donated, this can be examined further below in Figure 5. These donors came from various frequencies of prior event attendance. ACCESS Tech has been running donation events since 2019 and McMaster has run collection events since 2009, so seeing that 60% of donors interviewed reported this as their first event is an interesting marker that there is still new interest for this program. It also demonstrates the importance of communication efforts of these events on campus because the community is always changing as new students and staff join the institution. Returning donors, second and multiple event regulars also represent donors' ongoing need for avenues to ethically dispose of their e-waste and willingness to wait for another ACCESS Tech event rather than simply disposing of waste themselves.

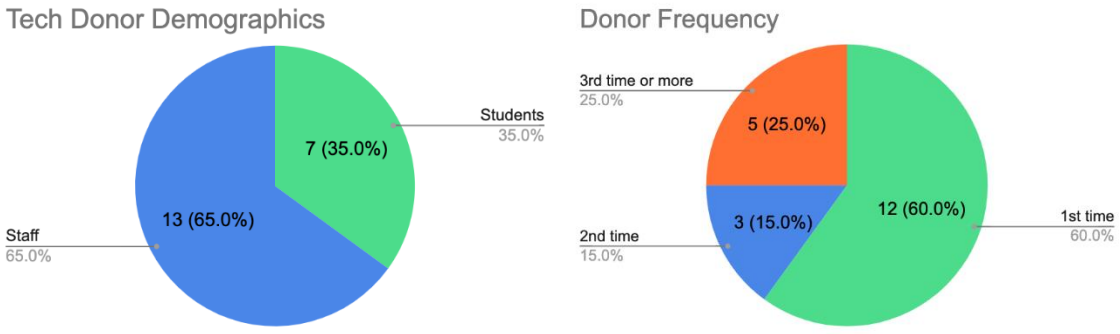

Figure 4: Donor demographics (Left) and Frequency from the ACCESS Tech Donation Event (Right)

Finally, an interesting pattern arose between comparing the upcycler and donor data from both studies. Looking at Figure 5 below, two bar graphs were constructed to show the top requested electronic items needed as was responded by the upcyclers surveyed compared to the cumulative donation items brought in by the donors surveyed. A symbiotic relationship between the wants of upcyclers (left figure) and donations of e-waste by the donors (right figure) can be directly matched in quantity in the case of many item types. From looking at the item types of extension cords, laptops, monitors, computers, and headsets, the requested equipment for upcyclers can be accommodated partially or fully from a single donation and reuse event. This demonstrates the e-waste reuse potential that can exist on a post-secondary campus. It would be pertinent to explore a larger scale survey to conduct a more thorough assessment of the accuracy of the symbiotic nature to the supply and demand of electronics. However, it is interesting to see that specific items student upcyclers need are directly being brought in by donors from the institution who no longer need them. This was surprising to me as I assumed most institutional equipment would lack quantity or quality for student upcyclers.,

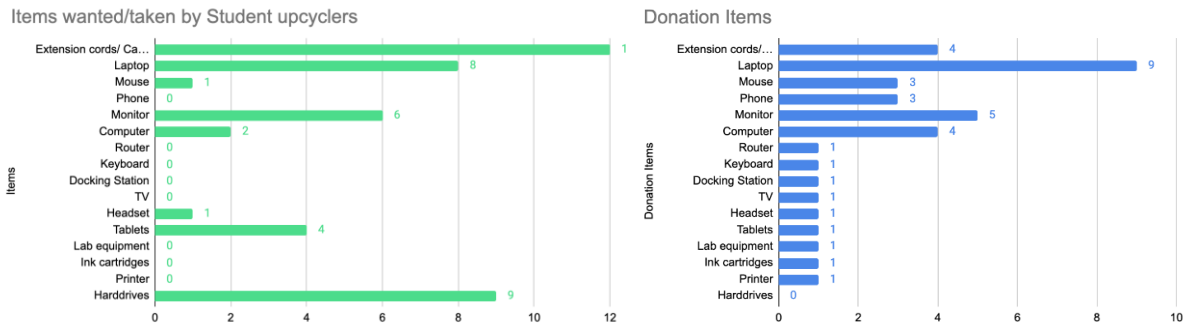

Figure 5: Types of Items wanted by Student Upcyclers (left) vs. Type of Donations (right)

Discussion

Long Term E-waste Management Strategy

From examining the e-waste strategies of many Canadian post-secondary institutions as well as the results of the research done on the ACCESS Tech initiative at McMaster, two patterns are clear. There is little consistency between the innovative e-waste management strategies of different institutions and there is under-researched potential on campuses to strive for greater e-waste reuse. Post-secondaries have a huge opportunity in becoming sustainable initiative hubs. Post-secondary campuses across Canada host smaller ecosystems where new sustainable initiative models can be prototyped, tested, and proven to thrive. Some excellent examples include the phenomena of community fridges and bee gardens, which have been popping up all around the country (Taekema, 2021; Pollinator Partnership Canada, 2023). These prototype models can then be expanded to other post-secondary institutions through information sharing. The current barriers to this ethical e-waste management model are the lack of centralized publicly available information, no guidance on how an institution can improve, and

lack of social pressure to shift to greater reuse. Similarly, to how the provincial government is instilling new policies to improve overall e-waste management by placing more responsibility on producers, post-secondaries, as mass-consumers of electronics should be held to this same standard. Ultimately consumers, such as large institutions, are making the decision on what to do with their end-of-life electronics. The current issue with policy is this lack of consumer responsibility. Legislation such as the current requirements by the Ministry of Environment for institutions to submit waste audits and achieve 60% diversion rates should be enhanced to ensure e-waste is repurposed and recycled (Stauch, 2012). This is a great long-term approach to ensure mandatory large-scale e-waste management change.

The McMaster E-waste Management Framework

For short-term strategies to enhance e-waste management, I believe sharing a guide for what an approach to better management could look like is a great resource. To this guide on how post-secondaries can expand their e-waste management strategies a framework was developed. The McMaster E-waste Management Framework was inspired by the "Reflective Learning Framework" created by Dr. Kate Whalen, which explored levels of improving students' learning from reflection work (Whalen, 2018). It was also based on my knowledge of the ACCESS Tech program at Master along with the new information I discovered through my literature review of external Canadian institutions. As seen in Figure 6, the pyramid style approach offers schools six levels of commitment to enhancing their e-waste management strategies. It also challenges institutions to work their way up the pyramid hierarchy, building on previous levels, to continue to innovate and improve as more resources become available. As an institution works their way up the pyramid they will diversify their available streams for collection, reuse, and donation to filter out as much e-waste material as possible before recycling is necessary.

The E-waste Management Framework focuses on improvement in three areas: recycling, reuse, and awareness. Lower levels of commitment and potential impact are focused on recycling. Recycling is far more beneficial than improper disposal of e-waste; however, it still means accepting that we have reached the conclusive "end-of-life" of the item. Creating awareness on campus for the impacts and opportunities of e-waste is an ideal midpoint between required resource commitment from the institution while continuing to produce a large impact on public perception. Finally, institutions should aspire to continue to expand e-waste management to eventually commit to adopting reuse strategies. This prolongs the life of electronics, and the institution can cultivate goodwill by helping those in need in the community. Each of the six levels of commitment will be discussed further to present tangible sub-goals for a post-secondary institution to follow, see Table 3. Sub-goals of neighboring levels may be mixed and matched in order to produce the institution's desired e-waste management outcome. Institutions are also encouraged to jump forward past lower levels of the hierarchy in development of their own systems and insight is welcomed of new innovative strategies that can be included in a future model co-created by Canadian post-secondary institutions.

Two crucial levels to comment on for the hierarchy are level four and five, Community Donation and Expanding Student Reuse respectively. It is important to recognize that some institutions will have an easier time donating to the community while others will find it easier establishing student reuse avenues. The pinnacle of these two levels is ensuring that post systems exist and are well developed. These two levels hope to ensure multi-levels of donation potential.

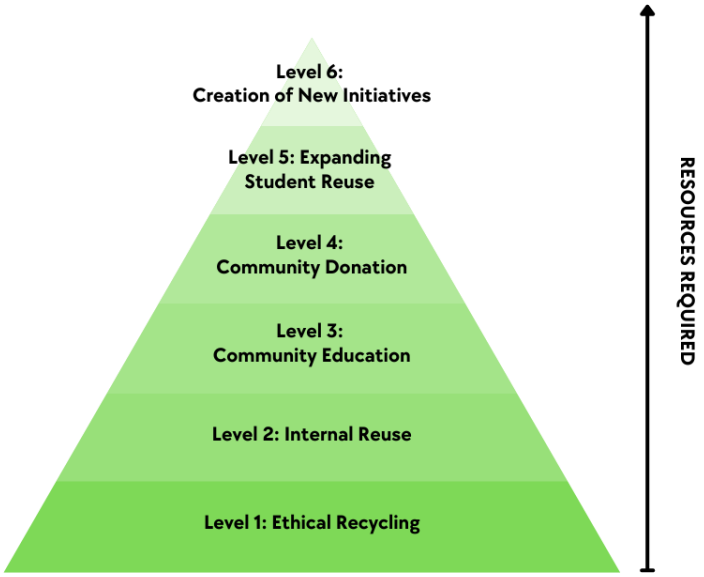

Figure 6: Levels of the McMaster E-Waste Management Framework for Post-Secondary Institutions

Table 3: Tangible Responsibilities for Institutions to follow in each level of the E-waste Management Framework

Levels of E-waste Management Strategies for Post-secondary Institutions
1. **Ethical Recycling** ❑ Partnership with third party recycler ❑ Positive Incentives and Negative Motivators for Community ❑ Collection Strategy
2. **Internal Reuse** ❑ Department based responsibility ❑ Platform for Reuse

3. **Community Education + Expanded Recycling** ❑ Information Graphics ❑ Campus Events ❑ Accessible Community Recycling
4. **Donation** ❑ Partnership with local non-profit ❑ Strategic Donor searching ❑ Electronics Refurbishment ❑ Targets for donations received ❑ Communicating Impact
5. **Expanding Reuse Opportunity** ❑ Internal Student Reuse ❑ Reuse Events ❑ Permanent Electronic Waste Location on Campus ❑ Meeting Student Needs
6. **Creation of New Initiatives** ❑ Student/Staff Collaboration ❑ Idea Generation ❑ Implementation ❑ Information Sharing

Levels of commitment

Level 1: Ethical Recycling

The first level of e-waste management strategy is ensuring thorough and ethical recycling. Subgoals of this category include partnership with a third-party recycler, positive and negative motivators, and establishing a collection strategy. Partnering with a third-party recycler is crucial to ensure ethical recycling. AASHE recommends this recycler be certified under the e-Stewards and/or Responsible Recycling (R2) standards to guarantee quality of work (SERI-Sustainable Electronics Recycling International, 2021). It is also recommended for this recycler to be local to minimize transportation emission effects.

After this the challenge becomes enforcing staff to utilize the recycling service and bring in their items rather than improper disposal. This can be done through establishing a combination of positive incentives and negative motivators. Positive incentives include verbal encouragement to donate or free gifts for those who bring items in. Negative motivators include charging an additional fee for a staff computer which will cover the cost of recycling or fining people found in violation of proper recycling. Finally, a collection strategy for how these items will get to the recycler is necessary. Common practices, as researched from STARs reports, involve placing periodically cleaned physical e-waste bins/security cages around campus to create focal points for drop off. Otherwise, collecting during special events or scheduling individual pickups

encourages consistent donations. Upon completing any combination of these subgoals the institution will host an adequate recycling strategy and can begin optimizing to ensure high quantitative yield. The weight of items recycled is crucial to measure the success of this level by comparing it to the total quantity of electronic waste generated.

Level 2: Internal Reuse

Upon adequate adoption of recycling amongst staff of the institution, an internal reuse system can be established. This will introduce recycling in a controlled small-scale manner without student involvement. Departments can begin the process by hosting a specified drop-off point within their office for e-waste. Staff can bring their items to this location and others can stop by to reuse anything of interest to them. Once proven to be successful a larger scope can be accommodated for. This would include the development of an online platform, for staff to post and donate items they no longer need to others. This portal would serve as a hub for the beginnings of a reuse strategy.

Level 3: Community Education + Expanded Recycling

Before expanding recycling opportunities to include students, it is crucial the student body is well informed on e-waste and its potential. Education initiatives can be highly impactful if hosted through the institution's sustainability office (or equivalent). This would begin with something simple like a social media campaign presenting key e-waste information. Following online communication, interacting directly with students through in-person events is ideal. As was observed at Carleton, hosting a lecture series from an expert open to questions would do wonders for increasing student perception and understanding of e-waste (Carleton, 2021). These educational events can be modeled to fit each unique school's identity to increase awareness. Furthermore, engaging passionate students in helping plan these events is always a good idea. Finally, the institution can feel confident in expanding recycling availability to students. This can include placing additional e-waste bins in popular student locations and including access to battery and lightbulb disposal. Furthermore, phone bins are very popular with students and therefore encouraged.

Level 4: Donation

The introduction to establishing e-waste reuse is probably the largest jump in commitment for a post-secondary institution. This is because the institution must now examine all the items to be recycled and assess individually if they have the potential to be reused by someone in need. When schools deal with thousands of items of e-waste annually such individual care is not feasible. Luckily these in-depth examinations can be constrained significantly if the institution reaches out to a local non-profit. Meeting the requirements for the items a non-profit needs will allow e-waste sorting to become highly efficient. For example, if the non-profit is looking for computers from 2017 or newer for its community, a simple search of the product number of an item will reveal this information. The beauty of electronics is that they are highly documented online, and most any key-term can be searched to identify an item of interest.

After securing a partnership with a non-profit who matches donations to people in need, the search for consistent donors begins. An advertising campaign should be run to promote e-waste donation events to both students and staff. After receiving donations, any items matching specifications will be sorted, wiped of any sensitive data, and refurbished lightly. Data wiping will ensure that hard drives in the item can be reused. The final step is to send items to the non-profit consistently and set SMART style goals for the number of items the institution is hoping to donate annually. This number can grow as resources become available and the new initiative gains momentum. One final way to create impetus for level four strategies is to share "feel good" stories to both old donors and new community members. Asking the non-profit to provide pictures or quotes from people in need who received an item is great motivation to encourage others to continue to donate. It makes the positive impact feel much more meaningful.

Level 5: Expanding Reuse Opportunity

Expanding reuse to include students can make the program more logistically challenging, but the direct help from the institution can feel even more personal for students. This level includes planning and hosting multiple student reuse events to allow students the chance to grab any e-waste items they need, for free, that could not qualify for donation to nonprofits. Although it may seem unfair that students get worse items, depending on the requirements of the non-profit, students may get access to items only 4-5 years old. In terms of storage devices, cables, monitors, laptops, and cellphones this age difference is negligible. Furthermore, as could be seen in the research study data results at McMaster, student reuse is very promising considering the quality and quantity of items students are willing to reuse. Therefore, it is encouraged for institutions at this level to bring as many of their leftover e-waste items as possible to student events to gauge the interest and threshold of older items desirability. Finally, along with reuse events another subgoal for this level is to eventually transition the event-model into more of a "Free Store", offering students a permanent space they can explore free electronics. This was observed in the STARs report of Laurier and proved to be very effective at showcasing the school's commitment to a circular economy (Wilfrid Laurier University, 2021).

Level 6: Creation of New Initiatives

As the recycling and reuse strategies expand at an institution to include the entire community and reuse shifts to being most favoured , it is time to get creative. This is arguably the most exciting level. The last level allows the institution to form teams of both students and staff to brainstorm potential enhancements to their program or completely new initiatives. It encourages future learning and innovation. This may look like forming a new club to engage students with staff mentors or even the initiative's inclusion in an academic sustainability course for credit. For example, this semester at McMaster, the ACCESS Tech program and library Makerspace partnered to offer new workshops for students to create art from old non-working phones we collected as e-waste. This level is all about trying different things, seeing what sticks, and when it does, sharing this information with others! No institution should have to start from scratch with their e-waste management nor should they feel they are isolated in an echo-

chamber. This level encourages making connections to institutions with other sustainability-oriented stakeholders; the final phase to an amazing e-waste management program.

Future Framework Application

Further research should be conducted to observe this framework's effectiveness and how it could be applied to an individual university. Additionally, this framework was only developed considering the key e-waste management strategy history and process of McMaster as well as supplementary information from three institutions, University of Alberta, Carleton University, and Laurier University. This represents a major gap in the framework's development and opportunity to make the framework even more robust in the future. Considering many other institutions e-waste management strategies was out of the scope of this inquiry, however it is a great area for potential future research to build upon and create an improved framework.

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Appendix A

Interview Questions: Donor experiences of donating IT to ACCESS Tech at McMaster

1. In this interview, we will be talking a lot about the motivations behind donating used tech. What brought you to donate your tech today?
2. Is this your first time donating your used tech?
   - What items have you donated before?
   - What items are you donating today?
3. How did you identify this item as donatable?
4. What would make it easier for you to donate your used tech?
   - What can we do to break down barriers for others to donate their tech?
5. What influenced your decision to donate over other methods of disposal (can cater it to the specific devices they are donating)?
6. Is there something important I forgot to ask? Is there anything else you would like me to know about at this time?

Interview Questions: Student experiences of 'upcycling' IT from ACCESS Tech at McMaster

1. What brought you to this event today? How did you find the event?
2. Is there something you were looking for? Did you find it?
3. Was there anything you didn't find today?
4. What are you planning to do with these items?
5. Why is this event valuable to you?
6. Is there something important I forgot to ask? Is there anything else you would like me to know about at this time?

Appendix B

Summary of Post-secondary Institutions STARs quantitative data for recycling, reuse, and E-waste management

School	**Material Recycled (tonnes)**	**Material Donated or re-sold for reuse (tonnes)**	**Total waste generated (tonnes)**	**% diverted by recycling**	**% of overall waste diverted by reuse**	Materials intended for disposal but subsequently recovered and reused on campus, performance year
Mohawk College	556.41	81.28	1193.16	46.63%	6.81%	5.94
U of British Columbia	1768	0	6284	28.13%	0.00%	no info
Sherbrooke University	267.2	15.04	704.93	37.90%	2.13%	no info

McGill University	540	0	2338	23.10%	0.00%	no info
Thompson Rivers	354.28	7.61	769.07	46.07%	0.99%	1.83
Toronto Metropolitan University (formerly Ryerson)	607	30	1822	33.32%	1.65%	no info
York U	1519.53	1308.16	4725.52	32.16%	27.68%	no info
Wilfred Laurier U	791.4	112.4	1870.41	42.31%	6.01%	**65.77**
U of Guelph	628	41	5105	12.30%	0.80%	no info
Carleton U	1983	11	3151	62.93%	0.35%	**68.64**
Humber college	874.11	25.99	2333.48	37.46%	1.11%	no info
Concordia	232.59	27.6	1250.13	18.61%	2.21%	no info
U of Alberta	1329.94	8.14	3821.75	34.80%	0.21%	**49.81**
Western	1428.73	0	3617.94	39.49%	0.00%	no info
U of Ottawa	1320.7	40.71	3020.31	43.73%	1.35%	40.17
UOIT	150.2	2.2	424.69	35.37%	0.52%	no info
University of Toronto Mississauga	374.49	0	1246.93	30.03%	0.00%	no info
Brock University	987.94	85.17	1981.05	49.87%	4.30%	no info
Dalhousie U	320	21	1394	22.96%	1.51%	21
University of Manitoba	283.96	6.52	1189.77	23.87%	0.55%	0.19
Nova scotia community college	77	0	293.9	26.20%	0.00%	no info
University of Victoria	473.79	0	2040.11	23.22%	0.00%	no info
Dawson College	60	0	229	26.20%	0.00%	2
Polytechnique Montreal	179.1	0	291.95	61.35%	0.00%	no info
HEC Montreal	78.7	2	261.5	30.10%	0.76%	no info
Ecole de Technologie Superieure	83.23	0	239.39	34.77%	0.00%	0
Royal Roads University	25.8	no info	35.9	71.87%	no info	no info
Simon Fraser University	736.77	27.45	1773.99	41.53%	1.55%	no info
University of Calgary	774.75	2.96	2743.81	28.24%	0.11%	no info

Fleming College	248.71	0	532.67	46.69%	0.00%	no info
Fanshawe College	316.61	19.41	1117.74	28.33%	1.74%	no info
University Laval	435	182	1573	27.65%	11.57%	no info
Ontario Tech University	150.2	2.2	424.69	35.37%	0.52%	no info
University of Saskatchewan	491.87	0	3897.46	12.62%	0.00%	0
Red river College polytechnic	116.63	651	1114.78	10.46%	58.40%	no info
Durham College	293.11	0	877.25	33.41%	0.00%	no info
George Brown College	1060	0	1822	58.18%	0.00%	no info
University of New Brunswick, Fredericton	142.32	0	879.16	16.19%	0.00%	no info
Langara College	103	0	235	43.83%	0.00%	no info
Seneca college	487.4	0	1350.45	36.09%	0.00%	no info
University of Waterloo	1,164	164	4,530	25.70%	3.62%	no info
British Columbia Institute of Technology	139.09	0	861.35	16.15%	0.00%	no info
Universite du Quebec a Montreal	40.49	0.45	383.04	10.57%	0.12%	no info
University of Northern British Columbia	53.43	71.03	309.89	17.24%	22.92%	no info
Northern Alberta Institute of Technology	458.16	0	1796.4	25.50%	0.00%	no info given
Sheridan College (Ontario)	403.45	5.51	1,441.83	27.98%	0.38%	no info given
Niagara College Canada	200.8	151.35	965.01	20.81%	15.68%	no info given
MacEwan University	178.66	93.73	785.7	22.74%	11.93%	no info given
University of Winnipeg	93.02	0	368.48	25.24%	0.00%	no info given

Camosun College	330.1	4.84	803.64	41.08%	0.60%	no info given
Selkirk College	46.38	0	258.01	17.98%	0.00%	no info given
Mount Royal University	177	0	633	27.96%	0.00%	no info given
Lakehead University	75.29	0	721.54	10.43%	0.00%	no info given
St. Lawrence College	131.59	0	336.47	39.11%	0.00%	0
Bow Valley College	64.91	0	154.19	42.10%	0.00%	no info

Appendix C

List of Canadian Post-secondary Institutions without a recorded STARS report

1. Champlain Regional College
2. Lethbridge College
3. Lambton College
4. John Abbott College
5. University of Toronto
6. University of Toronto Scarborough
7. University of Windsor
8. Olds College
9. Georgian College
10. Queen's University
11. McMaster University
12. Vancouver Island University
13. Southern Alberta Institute of Technology
14. Conestoga College
15. Yukon University
16. Acadia University
17. Nicola Valley Institute of Technology
18. African Institute for Mathematical Sciences
19. Bishop's University
20. OCAD University
21. St. Margaret's School
22. Grenfell Campus of Memorial University of Newfoundland
23. Canadian Memorial Chiropractic College
24. St. Clair College
25. Capilano University
26. Cégep de Sherbrooke
27. Vanier College
28. Universite du Quebec en Outaouais
29. Centennial College
30. College of the Rockies

31. Concordia University of Edmonton
32. University of New Brunswick
33. University of the Fraser Valley
34. Université Téluq

List of Canadian Post-secondary Institutions with a recorded STARS report without sections of Interest

1. University of New Brunswick, Saint John
2. Douglas College
3. Saint Mary's University
4. Okanagan College
5. Universite de Montreal
6. The King's University
7. Loyalist College
8. University of Regina