UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Nitrile Glove Recycling Assessment

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Executive Summary

The UBC Zero Waste Action Plan has a target of 80% diversion by 2020 and ongoing reductions in the amount of waste sent to the landfill each year thereafter. Currently. Seven million nitrile gloves are discarded annually across campus, amounting to 28 tonnes spread across 26 labs. These millions of nitrile gloves make up 30% of the campus' lab plastics that are sent to the landfill and 1% of the university's overall waste. The Kimberly-Clark recycling program provides a potential mitigation pathway. This was the basis for the year-long pilot program at the Centre for Comparative Medicine (CCM), which began in June 2019. This report is intended to analyze the pilot program and provide a recommendation on its campus wide expansion with the functional unit of one year worth of gloves.

The Kimberly-Clark recycling program is a viable solution, but only for their brand of gloves. Once a glove is used, it is disposed in a separate container and collected for recycling. The closest recycling plant to UBC Vancouver is located in Edmonton and it is the customer's responsibility to organize and pay for shipping. Once there, the glove is recycled using a confidential process into products that would have otherwise been made with High Density Polyethylene, such as trash bins, park benches, and lawn furniture.

First the financial viability was analyzed. The capital costs are negligible as it is recommended to use existing resources. With data from VWR regarding the different unit prices of gloves that are currently purchased at UBC, it was calculated that the annual price for the functional unit would be between $400 thousand to $1.2 million, for low and moderate quality gloves respectively. The equivalent amount of Kimberly-Clark gloves would cost $525 thousand. The base case landfill costs for the six required trips, including shipping and dumping, is $4,100. The shipping cost for recycling is $19,000, which would be divided into how every many trips are needed. Large collection boxes would also be required for each lab which will cost $860, given that a new box is purchased for each of the three recommended shipments. Ultimately, savings are incurred if the campus currently purchases 18% moderate quality gloves and 82% low quality gloves and replaces them all with Kimberly-Clark Brand.

Then the environmental impact was analyzed. The shipping emissions for three trips to Edmonton is 3.8 tonnes of CO2e, as compared to 1.8 tonnes of CO2e emitted by the six trips to the landfill. But this is offset by the carbon credit provided by recycling materials and maintain the circular economy. Recycling the 28 tonnes of gloves (with 95% efficiency) emits 9 tonnes of CO2e. This is then compared to producing the same amount of plastic with virgin materials, which would emit 42 tonnes of CO2e. From these numbers, it is clear that there are extensive environmental savings by using the Kimberly-Clark recycling program instead of sending the gloves to the landfill.

Finally, the workflow for CCM was analyzed to provide a recommendation for the expansion. CCM has two sustainability coordinators that are integral in the success of the project. This position should be created at each of the 26 labs. There are small glove collection bins in each of the lab rooms that are merged into a larger bin the hallway on a need-be basis. Then, every two weeks the sustainability coordinators bring all of these gloves to the gaylord box in their garage. This 1m3 box held nearly a year's worth of gloves. The same workflow is recommended for labs across campus, but ultimately each lab will have to determine if that is possible with their respective safety measures and workforce.

Feedback from other instructions who started this program was positive. The program appears to be manageable, and with proper transportation logistics, and enough funding, it is a guaranteed success.

Table of Contents

INTRODUCTION **1**

BACKGROUND 1
METHODS 1

KIMBERLY-CLARK RECYCLING **1**

ANALYSIS **2**

ECONOMICS 2
Capital Cost *2*
Operating Cost *2*
Total Cost *3*
ENVIRONMENTAL IMPACT 4
Shipping *4*
Disposal *4*
Total Impact *5*
FEASIBILITY 5

RECOMMENDATION **6**

APPENDIX A: FINANCIAL CALCULATIONS **A1**

APPENDIX B: ENVIRONMENTAL IMPACT CALCULATIONS **B1**

APPENDIX C: ADDITIONAL FEASIBILITY RESOURCES **C1**

APPENDIX D: REFERENCES **D1**

List of Figures

Figure 1. CCM Workflow 5

Introduction
This project is intended to analyze the current nitrile glove recycling pilot program at the Centre for Comparative Medicine (CCM) and provide a recommendation to UBC SEEDS and UBC Green Labs on expanding the program across the UBC Vancouver campus. There are 7 million individual nitrile gloves discarded annually in UBC labs (Righter, 2019) across 26 lab buildings (Foote, 2020) and even more gloves are discarded through custodial and food services. The 28 tonnes of nitrile glove accounts for one percent of the campus' total waste and thirty percent of the campus' plastic lab waste (Fraser, 2020). By diverting nitrile gloves from the landfill, it will help UBC reach their Zero Waste Action Plan targets.

The project will compare two disposal options: the base case, sending nitrile lab gloves to the landfill along with other lab waste, and off-site recycling with Kimberly-Clark. The closest recycling facility that takes nitrile gloves is located in Edmonton, Alberta. The results will be analyzed for the functional unit of a year's worth of gloves, which is 7 million gloves amounting to 28 tonnes. The analysis begins once the gloves have been disposed on campus. It has been found that that the manufacturing process of nitrile gloves is similar across brands, occurring in southeast Asia, and as such the embedded emissions can be omitted. The recommendation will be substantiated by three quantifiers: the environmental impact, economics, and feasibility of implementation.

Background
The one-year pilot program at CCM began on June 1st, 2019. CCM was chosen to be the test lab because of a few of its unique simplifying characteristics. The lab is a standalone facility with standalone practices and a centralized purchasing structure (Righter, 2019). The standalone practices made changing protocols more effective and the centralized purchasing structure allows for the entire facility to use the Kimberly-Clark gloves, thereby eliminating contamination from other brands. CCM assigned two sustainability coordinators to oversee this project, both of whom were integral in its operation. Overall, CCM reports that implementing this project was a success. The new practices were adopted by staff within six months and the facility only required one shipment, of a box holding a cubic meter, of gloves in April 2020.

Methods
The values used in the economic analysis were obtained predominantly from UBC Facilities and VWR. Additional data was collected from CCM and online sources to fill in any gaps. Then the calculations followed simple arithmetic to reach a tangible result. The environmental impact analysis will follow the structure of a consequential life cycle analysis (LCA). Data was collected from a literature review and analyzed by the team to reach a final result. The feasibility study, including reports on glove quality was determined through discussion with CCM and feedback from an online survey sent to various institutions that participated in the Kimberly-Clark nitrile glove recycling program.

Kimberly-Clark Recycling
The recycling process is organized through the Kimberly-Clark corporation. They provide a recycling option for their own gloves free of additional charge. So, a corporation will purchase Kimberly-Clark gloves, use them, and then arrange to have them shipped to the nearest recycling facility to be processed. The only additional cost incurred to the organization is the cost of shipping. Only non-hazardous gloves

are accepted for recycling, which on the UBC campus is roughly 7 million individual gloves or 28 tonnes (Kimberly Clark Professional, 2011).

The actual recycling process of the gloves is confidential but involves shredding the gloves and using high heat to melt them into nurdles, which is the form of virgin plastic for injection moulding (Flannery, 2020). The recycling process is approximated by comparing it to that of high-density polyethylene (HDPE) and rubber. These nurdles are then made into various plastic items such as park benches, garbage cans, and lawn furniture, which would have otherwise been made using virgin HDPE .

Analysis

The future operation is unknown, so the analysis is intended to show the worst-case scenario so that if UBC operates with any value better than those proposed in the report, they will incur even more benefits. For the environmental impact, high, moderate, and low scenarios are analyzed to give a full sense of the possible impact.

Economics

The economic analysis of this project covered three major aspects: product purchase, shipping, and disposal. The analysis is intended to find both the capital and operating costs of the off-site recycling and compare them with current practices.

Capital Cost

The capital cost for starting the recycling program is negligible. The cost of purchasing additional recycling bins and plastic liners can be mitigated by converting existing trash bins, as per the recommendation of Kimberly-Clark (Morton, 2020). The cost associated with making posters for the recycling bins is also negligible. The only possible source for capital costs is hiring additional labour as the sustainability coordinator. It is assumed that this position will be filled by an existing employee so there won't be any additional salary requirements. These assumptions are based on the operations at CCM who required very little start-up funding (Morton, 2020).

Operating Cost

The operating cost can be subdivided into purchasing new gloves and disposing of used ones. VWR provided three different glove options that are purchased by UBC at a high, moderate, and low unit price. The actual breakdown on the amount of each gloves being purchased is undetermined. The analysis is completed for all of UBC's gloves so the actual operating costs/savings incurred for each lab will have to be further determined by them.

The first aspect of the operating cost, which does not have a base case counterpart, is purchasing the gaylord boxes to hold the gloves in the basement of each lab. VWR provided such a box to CCM free of charge but it is unlikely they will do so for the entire campus. Unfortunately, VWR did not report a price for these Gaylord boxes so the team assumed a price of $11/box (including a pallet) based on the quote from *Uline Canada* (Uline Canada, 2020). This amounts to $290 for the 26 labs on campus. The team assumes that these boxes could be reused, but if they cannot, purchasing new boxes for each of the 26 labs, three times per year (after each shipment) would cost $860. The detailed calculations are provided in Table 1, Appendix A.

Purchasing

VWR reported three different unit prices for gloves that are currently purchased by UBC at a high, moderate, and low price point. The unit price per glove were $0.56, $0.17, and $0.06 for the microgrip, supermax, and VWR powder glove respectively (Protheroe, 2020). The most expensive gloves were omitted from the analysis as it is assumed they account for a small fraction of total gloves and are purchased to fit very precise needs that may not be covered by Kimberly-Clark. Scaling these unit prices to the functional unit of seven million gloves gives a range of $1.2 million to $400 thousand spent annually on gloves at UBC. The detailed calculations are provided in Table 2, Appendix A.

Kimberly-Clark has agreed to extend the price for gloves sold to CCM across campus at a unit price of $0.07 per glove (Carrillo, 2020). Scaling this to the functional unit equals $525 thousand spent on nitrile gloves, if all facilities convert to Kimberly-Clark. The detailed calculations are provided in Table 3, Appendix A. CCM is pleased with the Kimberly-Clark gloves and even reported that they were better quality than the previous brand they purchased. Based on this feedback, the team has assumed that the Kimberly-Clark gloves are of equal, or greater, quality to the moderate gloves currently purchased. This means that by switching to Kimberly-Clark, all glove users will have either a comparable or improved experience with their nitrile gloves.

It is evident that the price to purchase Kimberly-Clark gloves fits somewhere between the existing moderate to low price points. The breakeven point, that is the ratio between moderate and low gloves that have to be purchased currently in order to spend the same amount as buying all of them from Kimberly-Clark, will be calculated once shipping costs are determined.

Disposal

Current disposal practices to the landfill has two price components, the shipping fee and the dumping fee. One garbage truck can hold 4.5 tonnes per trip to the landfill, this means that if UBC were to dispose of gloves separately, the 28 tonnes of gloves would require 6 trips per year. This is the scenario that is analyzed as it can be assumed that by diverting gloves from the trash, UBC would require 6 less trips. The shipping fee is $104/trip and the dumping fee is $125/tonne (Righter, Landfill Disposal Costs, 2020). Scaling this up to 28 tonnes of gloves means that UBC spends $4,100 just to send their nitrile gloves to the landfill. The detailed calculations are provided in Table 4 and 5, Appendix A.

The team expected to calculate the shipping rate based off of the price for CCM's shipment. But due to extenuating circumstances, that shipment has not been sent at the time of writing this report. So, the team found a quote from *Go Freightera* of $155 per 500-pound pallet shipped from Vancouver to Edmonton (Go Freightera, 2019). Based on this quote, it would cost $19,000 to ship the 28 tonnes of gloves to the recycling facility. This is the total value and each shipment will be a fraction of this cost. It is likely that UBC could reduce this number by negotiating with shippers, but this is the worst-case scenario. The detailed calculations are provided in Table 6, Appendix A.

Total Cost

The total cost of the Kimberly-Clark recycling program is $545,000 annually. This includes purchasing seven million Kimberly-Clark gloves, purchasing three gaylord boxes for each of the 26 labs, and shipping 28 tonnes of gloves from Vancouver to Edmonton.

Using the goal seek function on excel, it is determined that in order to spend the equivalent amount on current practices, including shipping, disposal, and glove purchasing, UBC would have to purchase 18% of their gloves at the moderate price point and 82% at the low price point. If more than 216,000 moderate gloves are purchase across campus, there will be net financial savings by switching to the Kimberly-Clark recycling program.

Environmental Impact

The environmental impact analysis is spilt into two sections, shipping to the respective disposal site, and the actual disposal. Three methods are intended to be analyzed: incineration, landfilling, and recycling.

Research shows that the government of British Columbia currently bans the incineration of plastic (BC Ministry of Environment, 2017), and consequentially nitrile gloves. As such, the team did not do a thorough analysis of incineration as it is not a viable disposal option.

Shipping

The emissions of shipping the waste from UBC to the disposal site is calculated using the emission factors for a standard diesel burning vehicle, which is applicable to both the garbage truck and the freight truck. UBC garbage trucks are 'cleaner' than the standard, but the amount was unavailable, so this analysis is conducted for the standard diesel garbage truck.

The actual address for the Kimberly-Clark recycling plant is unknown. The team had hoped to have this info from the CCM shipment to improve the detail of the analysis, but that shipment has not yet been sent. So, the team made an assumption that the recycling plant would be in the Northeast Edmonton Industrial Area, 1,176km from UBC (Google Maps, 2020). The total emissions, including the carbon dioxide, methane, and dinitrogen monoxide, is 1.3 tonnes CO2e per trip. However, it is impossible for all of the gloves to fit in one freight truck, so the team also analyzed the emissions for three trips (one per semester) and six trips (equivalent to landfilling), those would emit 3.8 tonnes CO2e and 7.6 tonnes CO2e per year, respectively. The detailed calculations are provided in Table 1, Appendix B.

The Vancouver landfill is located 26km from the UBC Vancouver campus (Google Maps, 2020). The emissions, accounting for the same compounds as above, is 0.3 tonnes CO2e per trip. But it has been previously determined that shipping all of the gloves to the landfill would require six trips and therefore for the functional unit, shipping to the landfill emits 1.8 tonnes CO2e per year. The detailed calculations are provided in Table 1, Appendix B.

Disposal

Kimberly-Clark's actual recycling process is confidential, so it was impossible to know how many emissions were released in the process. As such, the team found a report from the US Environmental Protection Agency (EPA) that calculated the emission from recycling material to make HDPE (which is the same material displaced by the gloves) and used these values for the calculations. It is also impossible to know how efficient the process is in converting nitrile gloves to plastic nurdles. Recycling chip bags is 97% efficient (Mikolay, 2020), meaning that for every tonne of chip bag recycled, 0.97 tonnes of usable material is attained. Chip bags are traditionally difficult to recycle, similar to nitrile gloves, so an estimate of 95% efficiency for the nitrile glove recycling is used. This is low enough to be the worst-case scenario but high enough to give a true representation. In producing 26.6 tonnes (95% of

28 tonnes) of HDPE from recycled material, 9 tonnes CO2e would be emitted (International, 2016). These emissions account for both energy use, with natural gas, and fugitive emissions such as carbon dioxide and methane. Natural gas is used in the analysis as it is Alberta's primary energy source (Canada Energy Regulator, 2018). This appears to be a decent estimate based on the fact that recycling 26.6 tonnes of rubber would emit 2.7 tonnes of CO2e. The true emissions are expected to be somewhere between these two numbers. All calculations are provided in Table 2 and 3, Appendix B.

There are essentially no emissions from landfilling nitrile gloves. They decompose on a 100-year lifespan which is too broad to analyze here. But, landfilling materials is still a poor choice for disposal. This is due to the fact that it occupies land which could be used in a more productive manner, and that it prevents the circular economy model (Leahu-Aluas, 2020). One way to quantify the impact on the circular economy is to allocate the emissions required to produce 26.6 tonnes of HDPE from virgin materials to the base case. As by removing the nitrile gloves from the circular economy, and assuming that the HDPE products must still be made, you would need to build them with virgin materials. Using the same EPA report as above, the emissions from producing 26.6 tonnes of HDPE from virgin materials is 42 tonnes CO2e. This again accounts for energy use from natural gas and fugitive emissions of carbon dioxide and methane. The calculations are provided in Table 4, Appendix B.

Total Impact

The exact environmental impact of the Kimberly-Clark recycling program is unknown but given the reasonable and conservative assumptions made here, it is clear that the program provides an overall environmental benefit. If the recycling program uses three or six trips, the overall annual emissions are 12.8 tonnes CO2e and 16.6 tonnes CO2e, respectively, which includes recycling 95% of the gloves. Current practices, of landfill disposal and virgin plastic production, has an overall annual emission of 43.8 tonnes CO2e. Therefore, the total, worst-case scenario emission savings are 27 tonnes CO2e every year.

Feasibility

The sustainability coordinator at CCM reported that their workflow was efficient and manageable (Morton, 2020). A graphic of this workflow is Figure 1.

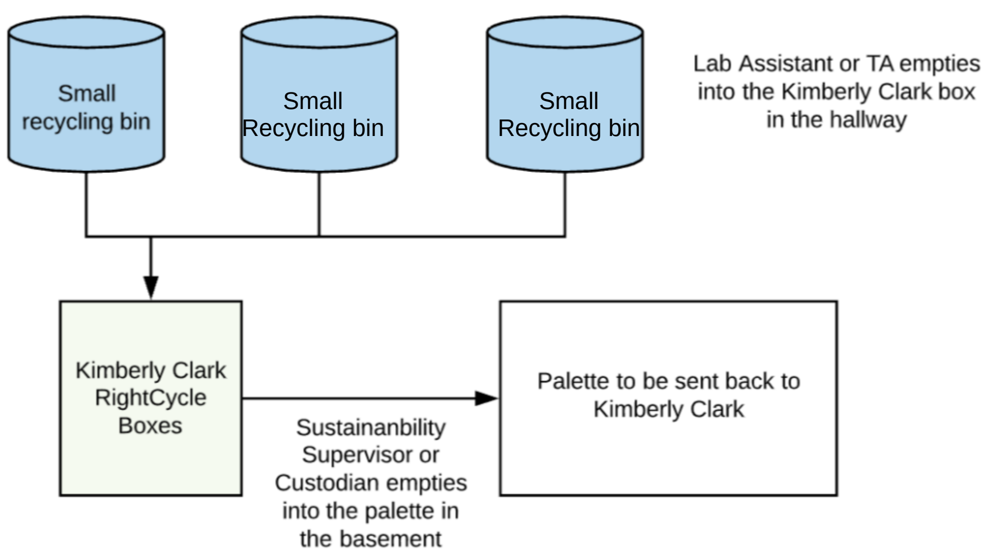

Figure 1. CCM Workflow

To ensure successful implementation this set up should be established when the program is started. The benefit to this workflow is that the capital cost is low and very few additional materials are required. The small recycling bins are converted trash bins. By diverting the gloves, less trash is generated, and a portion of the existing bins can be converted to hold recyclable gloves. CCM attached an infographic shown in Figure 1, Appendix C that helped staff differentiate between the bins. Within six months CCM staff was adjusted to this program and there was very little contamination (Gray, 2020). At CCM, the little bins in each room are merged in a larger cardboard bin in the hallway by the sustainability coordinator when they became full. The hallways of CCM had enough space for this to not be a hazard but other universities reported that having bins in the hallway contradicted their fire safety plan. CCM did report, however, that the cardboard bins were difficult to disinfect and would have preferred all bins to be plastic (Morton, 2020). This is something that each lab building will have to determine for themselves. Then, 2-3 times per month, the sustainability coordinator collects the gloves from the mid-size hallway boxes and brings them to the pallet in their garage. CCM had these facilities available to them so implementation was not difficult. This is again, something that each lab building will have to look into for themselves. Multiple institutions reported that the space constraints in their labs was a significant factor in discontinuing this program.

Two institutions reported that recycling the gloves is marginally more work but manageable and one source reported that there was no noticeable change in work to recycle the gloves once the system was implemented. The main issue that institutions incurred once they had set up this project was having a collection box that was not accessible to the majority of campus. This substantially increased the workload for those overseeing the project. The University of Washington also relied on volunteers to run the recycling program and were ultimately unable to attract enough manpower. However, this should be mitigated by assigning a sustainability coordinator to each lab.

Every respondent that stopped using the Kimberly-Clark Recycling program cited that the actual environmental impact of recycling was unclear, and they were therefore unable to justify the change. The University of Washington also reported that nitrile gloves did not account for enough of their waste stream to justify continuing this program and started recycling a more abundant material instead. The uncertainty is unlikely to be a problem for UBC as this report also investigated the environmental impact of the change. Increased costs were also a problem. The University of California Davis found that the high cost of shipping deterred certain facilities with a smaller budget. This prevented campus wide buy-in and reduced their overall impact.

There was also concern reported for contamination when labs were shared. Institutions worried that if other lab users disposed of non-Kimberly-Clark gloves in their bins the whole shipment would be discarded. Responses also recommended clear communication with custodial staff, as they had seen instances of bins with recyclable gloves being disposed with regular trash collection.

Recommendation

The CCM pilot program was a success. Pairing their success with the positive calculations seen previously for environmental impact and cost, the final recommendation is to proceed with the expansion of the Kimberly-Clark recycling program across UBC campus. The team recommends shipping the gloves to the recycling plant three times per year, at the end of each semester (merging the two summer semesters into one). This will have a net savings of 30 tonnes of CO_2e for every year of operation. And provided less than 82% of the gloves purchased across campus are of the lowest quality and price, the campus will incur overall financial savings. The program is feasible if it can follow a similar workflow to that of CCM. The most important aspect of that workflow is designating one to two sustainability coordinators per lab building. It is then recommended to collect gloves within the lab using existing trash bins with an attached informative sign. Then, labs should have one larger collection box per floor so that the sustainability coordinator can easily dump the gloves from the lab when they start to fill. The easiest way to collect all of the gloves would be to have one gaylord box per building, stored in the basement, or wherever is possible, for the gloves to ultimately collect. When ready for shipment, the gloves from each building can either be accumulated in one larger shipping container or shipped as individual pallets.

In order to implement this project, further analysis should be completed for each individual lab. Specifically, for the financial and feasibility section. This analysis shows an overall savings across campus, but evidently that is the simplified truth. Labs that do not incur savings by switching to the Kimberly-Clark recycling program could access available financial incentives to cover any extra costs. Further analysis could include custodial and food service gloves. The models and equations presented here are valid for both of those groups. The only variable that needs changed is the volume of gloves and their quality.

Overall, by implementing this project, UBC suffers no loss and eliminates thirty percent of their plastic lab waste and one percent of their overall waste. This project is a worthwhile next step in helping to reach the UBC Zero Waste Action Plan targets.

Appendix A: Financial Calculations

Table 1. Gaylord Box Purchasing (Uline Canada, 2020)

Size	Brand	Price	Units
0.76 m3	Uline	$ 11.05	per box
	Total	$ 861.90	annual

Table 2. Conventional Purchasing (Protheroe, 2020)

Quality	Brand	Price	Units
High	Microgrip	$ 56.05	per 100
	Microgrip	$ 0.56	per glove
	Total	$ 3,923,500.00	annual
Moderate	Supermax	$ 35.95	per 200
	Supermax	$ 0.18	per glove
	Total	$ 1,258,250.00	annual
Low	VWR Powder	$ 400.78	per 1000
	VWR Powder	$ 0.06	per glove
	Total	$ 392,350.00	annual

Table 3. Kimberly Clark Glove Purchasing (Carrillo, 2020)

Quality	Brand	Price	Units
Moderate	Kimberly Clark	$ 14.99	per 200
	Kimberly Clark	$ 0.07	per glove
	Total	$ 524,650.00	annual

Table 4. Conventional Disposal Trips (Righter, Landfill Disposal Costs, 2020)

Amount	Value	Units
Gloves	28	tonnes/year
Weight per trip	4.5	tonnes/trip
Total	6	trips/year

Table 5. Conventional Disposal Cost (Righter, Landfill Disposal Costs, 2020)

Fee	Price	Units
Dumping	$ 125.00	per tonne
Shipping	$ 104.00	per trip
Total	$ 4,124.00	annual

Table 6. Recycling Shipment Costs (Go Freightera, 2019)

Fee	Price	Units
Shipping	$ 155.00	per 500lb pallet
Total	$ 19,136.14	annual

Appendix B: Environmental Impact Calculations

Table 1. Transportation Calculations

			Emission Factor (U.S. Environmental Protection Agency, 2018)			GWP (IPCC, 2014)			Impact					
Vehicle	Fuel Efficiency (mpg)	Distance (miles)	CO_2 (kgCO_2/gallon)	CH_4 (gCH_4/mile)	N_2O (gN_2O/mile)	CO_2	CH_4	N_2O	From CO_2 (kg CO_2e)	From CH_4 (kg CO_2e)	From N_2O (kg CO_2e)	Total (kgCO_2e)/trip	Annual Total (kg CO_2e/yr)	Trips
Garbage	0.59*	17 ***	10.21	0.0051	0.0048	1	28	265	294.2	0.0024	0.0216	294.2	1765.3	6
Freight	5.9**	730 ***							1263.3	0.1042	0.9286	1264.3	1264.3	1
	[redacted]												3792.9	3
	[redacted]												7585.8	6

* (Zietsman, Lee, & Farzaneh, 2009)
** (Tuft, 2013)
*** (Google Maps, 2020)

Table 2. Recycled HDPE Manufacturing (International, 2016)

Energy Use (Btu/Short Ton)	Natural Gas Generation Emissions (lbCO_2e/million Btu)	Energy Generation Emissions (MT CO_2e/Btu)	Energy emissions (MTCO_2e/Short Ton)	Other Emissions [co2, ch4] (MTCO2E/Short Ton)	Total Emissions (MTCO2E/Short Ton)	Total Emissions (gCO2E/g)	Amount of Product (tonnes/year)	Total Emissions (tonne CO_2e/yr)
5330000	117	5.30704E-08	0.282865074	0.03	0.312865074	0.34	26.6	8.69

Table 3. Rubber Recycling (Institute for Environmental Research and Education, 2009)

Recycling Emissions (kgCO_2e/tonne rubber)	Amount of Product (tonnes/year)	Total Emissions (tonne CO_2e/yr)
103	26.6	2.7398

Table 4. Virgin HDPE Manufacturing (International, 2016)

Energy Use (Btu/Short Ton)	Natural Gas Generation Emissions (lbCO_2e/million Btu)	Energy Generation Emissions (MT CO_2e/Btu)	Energy emissions (MTCO_2e/Short Ton)	Other Emissions [co2, ch4] (MTCO2E/Short Ton)	Total Emissions (MTCO2E/Short Ton)	Total Emissions (gCO2E/g)	Amount of Product (tonnes/year)	Total Emissions (tonne CO_2e/yr)
23680000	117	5.30704E-08	1.256706371	0.2	1.456706371	1.61	26.6	40.46

Appendix C: Additional Feasibility Resources

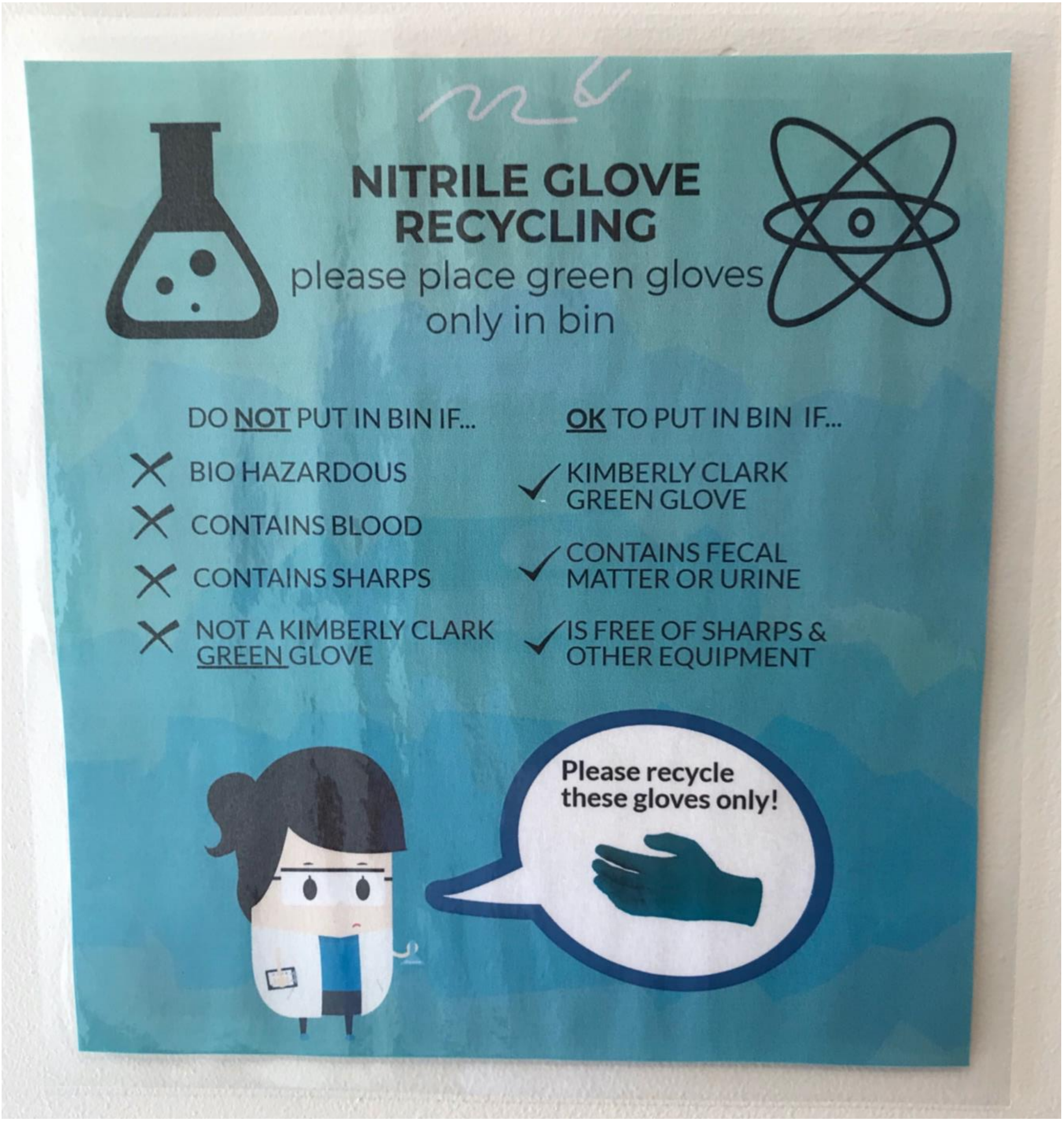

Figure 1. CCM Recycling sign (Riddell)

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