

ENGN2226

Final Portfolio

An analysis of takeaway coffee containers -
“Waking up to a more sustainable future”



Source: Fran Hogan, [www.publicdomainpictures.net]

Executive summary

This report analyses takeaway coffee containers, from a systems engineering perspective. It is written with the view of analysing how reusable coffee cups compares to disposable cups, with a special focus on sustainability and environmental impacts. As part of this a model which exclusively uses reusable cups is also evaluated. This investigation is performed using a holistic, multifaceted approach taking into account the experience of takeaway coffee buyers and baristas. It also looks at the environmental, human, cost and energy factors involved; comparatively analysing the systems over their lifetime. The report finds that; reusable cups have significantly less environmental impacts than disposables over their life cycle, and are more cost and energy efficient, so long as the reuse of the cup is maintained as these effects are seen to be cumulative. It is also found that there is support for the use reusable cups in baristas and coffee buyers, however challenges will be present in adopting a reusable cup only model.

Introduction

In a world with increasing consumption and a rapidly growing population, issues surrounding sustainability and resource management are becoming more and more important. A key aspect of any sustainability initiative is that of waste management. Last year Sustainability Victoria's annual report found that 588 kg of waste generated per capita in the state, over the previous year alone went to landfill (Sustainability Victoria, 2014). A proportion of this non-recycled waste would have been composed of composite packaging. An example of this is the laminated plastic, paper and aluminium foil often used to package long life milk in Australia; commonly referred to as Tetra pak . Due to its relatively complex structure, it is difficult and costly to process in order to recycle, requiring specialised technology with a comparatively low resell value (Xie et al., 2012). This then leads to landfill disposal, where components of it may exist in the environment for 100's of years.

In this report a familiar yet often over looked example of difficult to recycle composite packaging is analysed; the disposable hot beverage paper cup. For many people especially, coffee lovers, this is a product used once and disposed of daily with little thought as to the environmental impact. As will be presented; alternative biodegradable disposables have many limitations such that, at the current level of technology, the most sustainable option is to avoid disposables altogether and use a reusable cup to buy coffee. Extending this idea, reusable cups (specifically takeaway coffee cups) are evaluated in this report as a system; finding potential hurdles and areas from multiple aspects which may be improved as this system is adopted. These results taken together can provide an insight into a more sustainable future.

1. Quantitative analysis

In order to further motivate the discussion in this report a brief quantitative analysis is done on world usage of disposable cups and their impact.

1.1 Consumption of disposable cups and resource usage

A recent study on world paper cup consumption found that approximately 242 billion disposable paper cups are consumed around the world annually (Grischenko, cited in Fisher 2008). Starbucks, one of the world's largest coffee franchises purchased 2.6 billion cups in its 2006 fiscal year alone (Grischenko, cited in Fisher 2008). Due to its large global market share Starbucks is an appropriate case study to use as a standard practice estimate of how the takeaway coffee industry creates their disposable cups. A report in 2000 by the Alliance for Environmental innovation (AIE) in conjunction with Starbucks calculated various environmental impacts in the manufacture of a Starbucks takeaway coffee cup, their results are summarised in Table 1. For a single standard 16 ounce (generally AUS large) sized cup this equates to: 91 g of greenhouse gases produced, 585 KJ of energy used as well as 1.1 L of effluent flow and 14 g of solid waste produced (Alliance for Environmental Innovation, 2000). If we consider the huge number of disposable coffee cups consumed every year, the total resource use becomes staggering, and the environmental benefits of more sustainable alternatives obvious.

Table 1 Environmental impact of Starbucks 16-oz coffee cup, data sourced from (AIE, 2000)

Energy Usage		Water Emissions	
(MJ/10,000 16-oz cups)		(Kg/10,000 16-oz cups)	
Total	5.86	Biochemical Oxygen Demand (BOD)	0.39
Purchased	2.63	Chemical Oxygen Demand (COD)	5.18
Fossil Fuel Derived	2.09	Suspended Solids	0.63
Air Emissions		Effluent Flow	
(Kg/10,000 16-oz cups)		(L/10,000 16-oz cups)	
Total Greenhouse Gases	919.12		10935.65
Net Greenhouse Gases	357.70	Solid Wastes	
Nitrogen Oxides	1.18	(Kg/10,000 16-oz cups)	
Particulates	0.75		140.43
Sulfur Oxides	1.66		
Hazardous Air Pollutants (HAPs)	0.15		
Volatile Organic Compounds (VOCs)	0.37		
Total Reduced Sulfur	0.02		

2. Material factors

A discussion about the material challenges posed in designing a more sustainable disposable coffee cup is presented. Life cycle assessments performed on disposable and reusable cups are also evaluated in order to determine the best option from a material factors perspective

2.1 Post-consumer content disposable cup material limitations

A standard hot beverage paper cup is created from high quality bleached cardstock, formed into the shape of the cup and lined with a waterproof coating; typically a very thin layer of low density polyethylene (LDPE), hot cup lids are made from polystyrene and are readily recycled once separated (Alliance for Environmental Innovation, 2000). This laminated LDPE – paper material defines disposable coffee cups as a composite package and is inherently why they are so difficult to recycle, as the materials need to be separated using specialised technology in order to be sold as a commodity for reuse (Xie et al., 2012). This generally leads to landfill disposal. Part of the report put forward by the AIE in conjunction with Starbucks, was the research and development of a less resource intensive disposable coffee cup. The report highlighted a major limiting factor in its development; that post-consumer content in the lining in direct contact with the liquid is inadvisable due to the cups needing to pass healthy and safety standards (Alliance for Environmental Innovation, 2000). As post-consumer content cannot be used everywhere, this prevents an entirely recycled cup from being created which would mitigate most of its environmental impact due to manufacture. However some recycled material can be used in the cup as distinct separate layer on the outside, this type of cup was trialled in the AIE report with limited success due leaks in the seam of the cup (Alliance for Environmental Innovation, 2000).

2.2 Biodegradable cup material limitations

The AIE report did not address the waterproof lining being made from a non-biodegradable plastic. However a recent internet search of “biodegradable hot coffee cup” found a lot of manufacturers selling cups lined with Polylactic acid (PLA) which is a biodegradable thermoplastic produced from corn. In theory the PLA could enable the cup as a whole to be composted, thus removing any end of life waste. In 2010 a life-cycle assessment of disposable cups found that PLA had an embodied energy of 58.18 MJ/kg lower than that of LDPE, 76.7 MJ/kg, however PLA produced slightly more CO₂ in its manufacture (Häkkinen & Vares, 2010). The same article states that in a normal landfill scenario PLA will either not biodegrade or has the potential to decompose into methane which is a harmful greenhouse gas. It also explains that PLA is only completely biodegradable when composted in a large scale purpose built operation with temperatures kept at 60 °C and above (Häkkinen & Vares, 2010). Although an improvement on LDPE, a PLA coating does not remove the need for specialised end of life intervention to exist in order to avoid the landfill where it may have a large environmental impact, nor does it change impacts due to the cardstock it’s used on.

It is clear that due to these limitations, at current levels of material technology, it is not possible to create a feasible disposable coffee cup that avoids large environmental impacts in its manufacture and end of life disposal.

2.3 Comparative Life-cycle analysis of disposable and reusable coffee cups

The current major trends in the creation of sustainable disposable coffee cups have been analysed and significant limitations have been found in all methods. There exists an alternative which is the reusable cup. A reusable cup invests more energy and materials into a single cup, and with continued use lessens the environmental impact due to disposable cups by removing the need for them altogether. However it is not guaranteed that the impacts from a reusable will significantly improve on those of a disposable. As such a comparative life-cycle analysis is presented in order to evaluate the differences.

The life-cycle analysis (LCA) presented models the use of a reusable cup made by KeepCup (an Australian reusable cup manufacturer) and a paper cup to get coffee every day for a year in Australia. The KeepCups are made from Polypropylene (PP) with Polyethylene (PE) lids which are completely recyclable separated (Lockrey, 2011). The modelled paper cups are used once and disposed to landfill and the reusable cup washed every day in a dishwasher and disposed to landfill at the end of the year as worst case scenario estimation. The study published in the Journal of Design Principles and Practices assessed the indicators of: global warming potential (Kg CO₂ eq emitted) Land use, water use, solid waste, and embodied energy (Lockrey, 2011). The system boundary of the LCA is given in Appendix C, Fig. 1 and the results presented in Fig. 1 and Table 2.

Table 2 Results of comparative LCA, sourced from (Lockrey, 2011)

Impact category	Global warming potential	Land use	Water use	Solid waste	Embodied energy
Unit	kg CO ₂ eq.	Ha	KL H ₂ O	Kg	MJ
KeepCup (AUS) dishwasher	3.43	1.36E-05	0.101	0.22	36.1
Paper Cup	12.5	0.00615	0.931	3.21	282

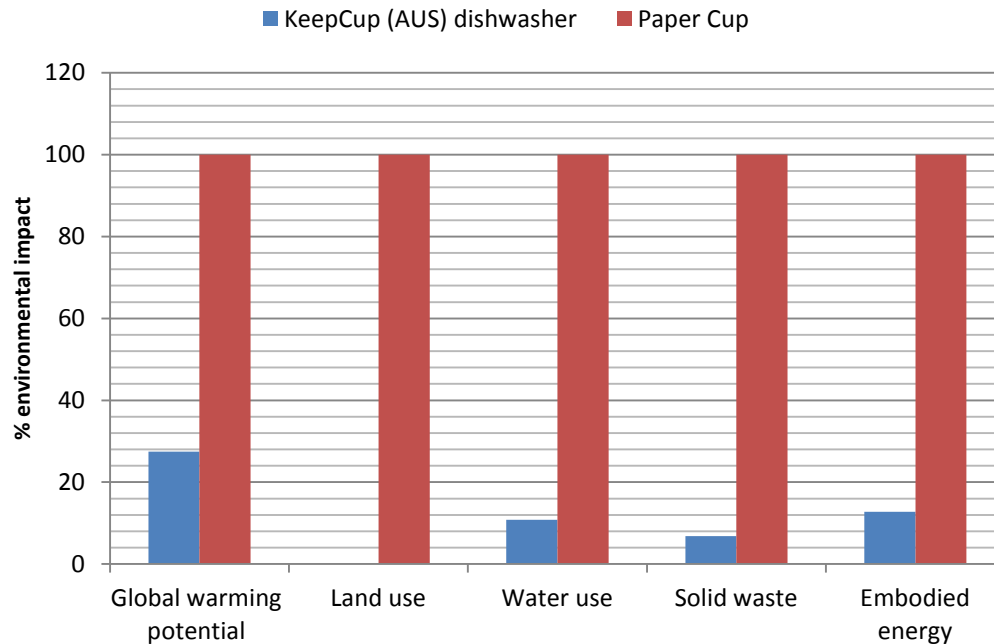


Figure 1 Percentage environmental impact comparison between reusable keepcup washed in a dishwasher daily and paper cup disposed daily over 1 year, figure made using data sourced from (Lockrey, 2011) on a log -plot

From this analysis it is clear that there is a greater than 65 % reduction in all environmental impacts measured, and in land use this figure is as high 99 %. The study also found that efficient hand washing of the reusable cup could further improve these results (Lockrey, 2011). Worth noting is the fact that most of these results could be immediately extended to reusable cups in general as the effect is cumulative and 1 year of use is at the low end of an expected cup lifetime.

2.4 Summary of material factors findings

To address the prevalent environmental impacts of disposable coffee cups outlined in section 1.1, making cups out of post-consumer content and biodegradable cups were investigated. It was found due to health and safety reasons post-consumer content cannot be used in the whole cup, limiting the benefits from this process. Neither does it improve recycling of the composite material. It was also shown that current biodegradable waterproofing coating does improve environmental impacts but must be commercially composted at over 60 °C in order to fully degrade into non-toxic products; otherwise it may produce harmful methane gas in landfill. Reusable coffee cups were shown to be the best alternative; reducing impacts by more than 65 %, even in the worst case scenario where they are disposed to landfill and not recycled.

3. Qualitative analysis

Building on the finding that reusable coffee cups are a more sustainable alternative to disposables, a qualitative analysis is done on reusable cups as a system. This is used to understand the perspectives of coffee buyers and baristas separately on reusable cups and the implications for them of adopting a model with only reusable cups. The analysis is based on qualitative data collected in the form of an online survey for takeaway coffee buyers, and an interview with baristas at two different café's.

3.1 Results and analysis of takeaway coffee buyers survey

The survey used was composed of a mixture of multiple choice and long answer sections. It had a sample size of 33, which is not statistically significant but is deemed to be appropriate for this type of qualitative study. A copy of the survey is given in Appendix A.1, and the results in Appendix A.2. The data from the multiple choice section was collated into percentages and that of the long answer was coded where each response could at most raise two topics, and the overall number of mentions of each topic was collected. The detailed results of this analysis are given in Appendix A.3. A summary of the first and second most common result for each question is given in Table 3.

In the analysis, Q1 was used to determine a valid response and only those answering yes were included in the rest of the results. From the survey responses a number of insights can be drawn. The first is that the majority of respondents thought there were benefits to reusable cups citing environmental reasons, and also to varying extents most respondents were not against only being able to buy takeaway coffee in reusable cups, most thought they would use a reusable cup to buy coffee in general as well. This implies that if a model of only reusable cups were to be put in place there would be some support for it. The survey also highlights significant drawbacks of such a model. The foremost of these is the inconvenience of washing and remembering the cup, with most respondents mentioning this as a negative. There is no easy solution to this as it is a defining characteristic of a reusable cup. To fully address it all washing should not be done by the user and cups should be available in store. A potential solution could be a third party collection and supply service that a coffee buyer pays to use and supplies café's with clean cups. However this type of large change is complex and would need further analysis to verify. Another concern raised is that of hygiene of the cups, though the risk due to this can be mitigated by café's simply refusing dirty cups.

Table 3 Summarised results of online survey of takeaway coffee buyers

	Q1. Do you buy takeaway coffee?	Q2. Do you believe there are benefits of using reusable takeaway coffee containers?	Q3. What were those benefits? (if any)	Q4. Do you believe there are negatives of using reusable takeaway coffee containers?	Q5. What were those negatives? (if any)
Metric	% respondents	% respondents	no. of mentions	% respondents	no. of mentions
1st most common response	yes [93.9%]	a lot of benefits [51.5%]	Environmental (less waste/pollution) [26]	some negatives [93.9%]	Inconvenience (washing , remembering it, carrying it) [20]
2nd most common response	no [6.1%]	some benefits [42.4%]	Aesthetic (better looking cup) [4]	no negatives [6.1 %]	Hygiene (if not cleaned, cup becomes unsafe/dirty) [6]
	Q6. Would you use a reusable takeaway cup to buy coffee?	Q7. Imagine a world where you can now only buy takeaway coffee using a reusable cup you brought to the cafe, how do you react?	Q8. If you thought of any positives about this idea, what are they?	Q9. If you thought of any negatives about this idea, what are they?	Q10. Do you have any other thoughts on reusable coffee cups?
Metric	% respondents	% respondents	no. of mentions	no. of mentions	no. of mentions
1st most common response	its likely [63.6%]	its an ok idea [54.5%]	Environmental (less waste/pollution) [21]	Forgetting cup (not being able to buy coffee)[12]	n/a (too few and varied responses to code)
2nd most common response	its not likely[24.2%]	its a great idea [27.3%]	Financial (savings from cafe not buying cups) [4]	General Inconvenience (wash/bring it, annoying for coffee shop) [8]	

3.2 Results and analysis of takeaway coffee makers interview

The baristas at the Little Pickle Café and The Coffee Grounds on ANU campus were interviewed to find how reusable cups integrate into the takeaway coffee making process and understand the general opinions of baristas on the subject. The notes taken in the interviews are given in Appendix B.2 Table 1, along with a copy of the questions and any prompts used in Appendix B.1.

The results of the interviews show that both café's baristas were for the use of the reusable cups, and at one of the café's a 50c discount is given to everyone who buys a coffee using a reusable cup. In general they did not state that it had a large impact on how coffee is made

although there is a preference for smaller sized cups that fit under the head of the espresso machine which do not need to be made by pouring a coffee shot into something else first and then the cup. One of the potential difficulties of a completely reusable model were due to the additional use of space if the cups do not stack and have to be left on the counter. Another is the difficulty in labelling the cup; as a marker is used on paper ones. The problem of having to guess the size of the cup in order to charge was also raised. It seems that all of these can be solved if a level of homogeneity is applied to reusable cups such that that they meet a standard in which they are predictable sizes, have a surface which can be marked by non-permanent marker and are able to stack to a certain degree. These standards may be difficult to enforce however if the use of reusable cups was common it would be simple to advertise in store what type of cup is accepted.

3.3 Summary of qualitative analysis findings

From the takeaway coffee buyers survey it was shown that the majority of buyers were for the use of reusable cups and to varying degrees also for a reusable cup only model. The main challenges against reusable use buyer raised were found to be inconvenience of having to wash and remember it, and the cup becoming unhygienic once used. The inconvenience of the cup is difficult to mitigate, although a third party collection and supply service which washes the cups is suggested as an alternative which would need further analysis to verify. The risk associated with unhygienic cups could be easily prevented by café's refusing to use a cup which could contaminate their equipment. The interviews with baristas found both to be for the use of reusable cups. The difficulties of only using reusable cups were due to inconsistencies in different cups, and may be prevented if a type of reusable cup standard is created.

4. Energy factors

Reusable cups as a system do not lend themselves directly to an energy/mass flow or more conventional analysis due to the simplicity of their action as a passive container. As such it was determined an energy factors analysis which takes into the energy per reuse and total energy as compared with a disposable cup should be performed. This is based on an analysis done by Hocking in 1994.

4.1 Energy per use of reusable cup vs. disposable cup

To model the total energy per use of a reusable cup we use Eq.1 where M is the embodied energy of reusable cup due to manufacture, X is the number of uses and W is the energy used to wash a cup (Hocking, 1994).

$$\text{Total energy consumption per use of reusable} = \frac{M + XW}{X} \quad (1)$$

This assumes that the reusable cup is used only once before it washed again before reuse, which due to the concerns about hygiene that were raised in the qualitative analysis is reasonable assumption. The energy use of the disposable paper cup is just that of its embodied energy.

The reusable cup types used in the analysis are ceramic, heat proof glass and non-foamed reusable polystyrene. The embodied energy of these materials is taken from Hocking. Composite cup types of metal and plastic are ignored due the difficulty in recycling and end of life concerns presented in the material factors section. The energy to wash a cup is based off the LCA of Lockrey who used energy efficient dishwasher in 2011 of 0.55 kWh per wash with 70 cup capacity per wash; this is assumed to be equivalent to dishwasher efficiency today. Embodied energies presented are based on a cup size of approximately 16oz (AUS large size), and given in Table 4. A plot of the total energy per use of the different cup types is shown in Fig. 2.

Table 4 Embodied energies of cups and energy per wash data taken from (Lockrey, 2011) and (Hocking, 1994)

Cup type	Embodied energy (kJ/cup)	Energy per wash (kJ/wash)
Ceramic	14088	28.3
Heat proof glass	5501	28.3
Reusable polystyrene	6300	28.3
Paper disposable cup	585	n/a

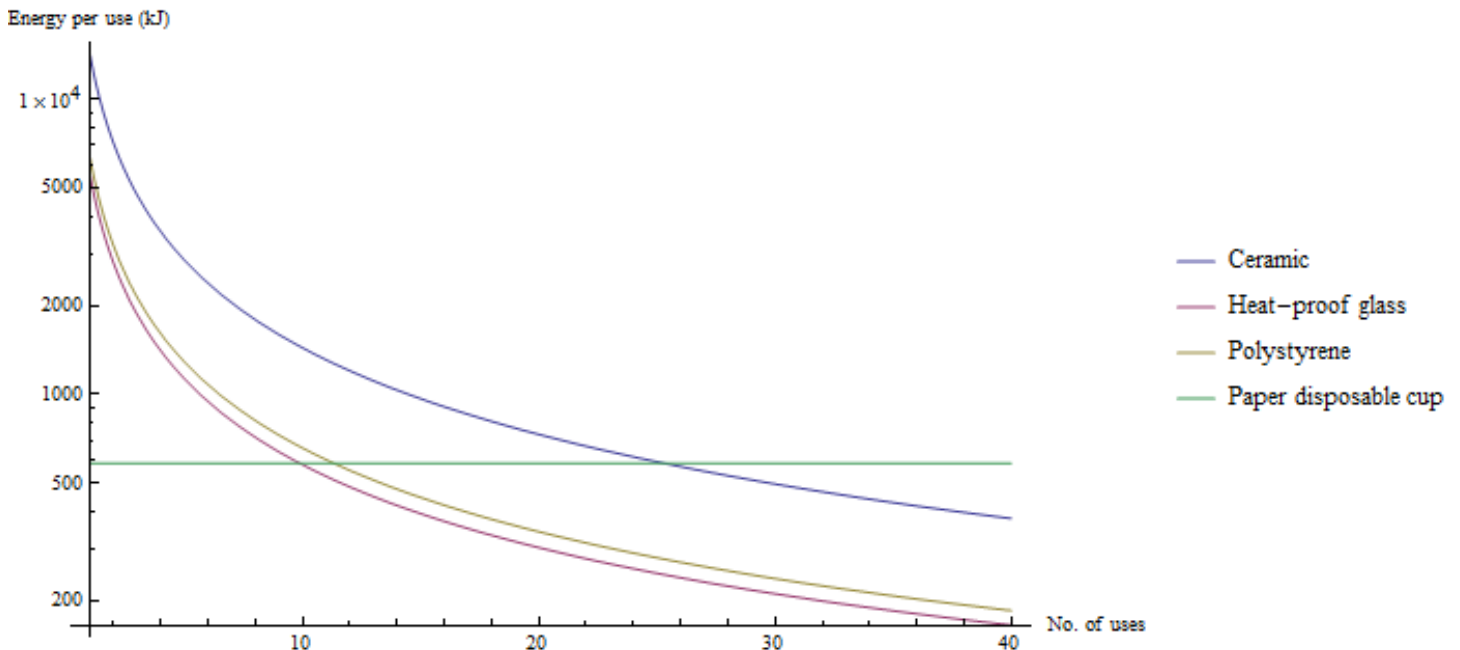


Figure 2 Total energy per use of various reusable cups as a function of the no. of uses, plotted on a log -plot

From the plot of the of energy use per wash it can be seen that all cups break even with the disposable after about 26 uses, and the total energy per use approaches the energy per wash for large washes. The glass, having the lowest embodied energy breaks even with the disposable first, closely followed by the plastic with the ceramic taking almost twice the number of uses then either. Exact break even calculations are shown in Table 5.

Table 5 Energy break even calculations of various cup types washed in dishwasher

Cup type	Break even no. of uses
Ceramic	26
Heat proof glass	10
Reusable polystyrene	12

If we assume that most plastics suitable to use in a reusable cup, have embodied energies on the same order of magnitude as polystyrene; then the general result of plastic and glass cups being significantly more energy efficient than ceramic holds. Furthermore both plastic and glass can be more efficiently recycled than ceramics, compounding the observation if net energy given back into new feedstock is subtracted from the embodied energy. Based on this result it is suggested plastic or glass reusable cups be used whenever possible.

4.2 Potential for reusable cups to be less energy efficient than disposable cups

It is also worth noting how sensitive the breakeven number of uses is to the relative efficiency of the washing process. For instance if a small disposable cup with an embodied energy half that as before at 290 kJ is compared with the same reusable cups and a dishwasher only ever packed with 10 cups equivalent to 198 kJ per wash, it would take 69 uses for the polystyrene cup to break even and more than 150 for a ceramic one. As long as the energy per wash is less than that of manufacturing a disposable cup eventually all reusables will become more energy efficient than the disposable, however in situations where cups are lost or not reused enough they are far more energy intensive than a disposable.

5. Human factors

A human factors analysis is presented on the use of reusable cups. As this analysis is assumes the use of reusable cups already available on the market, ergonomics and anthropometrics of specific cups can be ignored with the assumption they have been considered in the design of the cup. Instead a focus on workplace health and safety and risk management is used.

5.1 Reusable cup risk assessment and management

From the qualitative analysis we can see that baristas did not think reusable cups significantly impacted the way coffee is made and thus did not pose an additional safety concern, especially

if standard sized reusable cups are used as suggested in section 3.2. However if all the cups were reusable that people bring themselves, there is risk generated from the unknown state of the cup. One such factor raised in the qualitative analysis is the hygiene of a cup, and the other is the material stability. These pose risks of contamination and injury due to a cup breaking.

The risk control performed follows the process set out by WorkSafe Victoria, given in Fig. 3; in which elimination of the hazard should be the first risk control attempted WorkSafe Victoria, 2006).

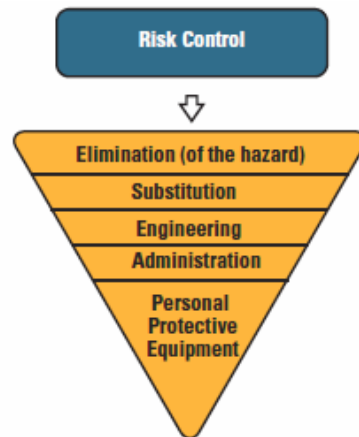


Figure 3 Ideal risk management process showing preferred actions from the top down (WorkSafe Victoria, 2006).

Considering that in the energy factors section it was recommended that only plastic or glass reusable cups should be used, we can see the greatest risk from injury due to breakage is from glass as it produces shards. This would be a risk not only for baristas but also users who carry it with them. As such to perform hazard elimination it is suggested that either glass cups are not used, or if the barista identifies any cracks in the cup they refuse to make coffee with it. The risk of contamination due to unhygienic cups can also be eliminated if the barista refuses to use a dirty cup, and coffee buyers understand to wash their cups adequately.

6. Cost factors

Life cycle costing (LCC) is performed on a reusable cup and compared with that of a disposable in order to ascertain total costs over an expected life time of a cup. This total cost is then used to determine the payback period in terms of the number of coffees needed to be bought in order to pay off the cost of the reusable cup.

6.1 Comparative life cycle costing of reusable cup vs. disposable cup

The LCC was conducted in accordance with the National Audits Office better practice guide, including ongoing and end of life costs (Australian National Audit Office, 2001). A plastic reusable cup assumed to be bought from the store KeepCup was used, in keeping with the LCA in section 2.3. The life cycle of the reusable cup was given as 3 years/1095 days as this is the

expected use time (Keepcup.com.au, 2015). The costing was done on the basis that a coffee is bought once every day over the life cycle, the disposable cup is thrown away and the reusable cup washed. The cost of the disposable cup was taken as its wholesale cost, and the ongoing cost of water and electricity used to wash the reusable was accounted for. The dishwasher specifications given in the LCA were used again. Table 7 details all data used in the costing and its source. The results of the costing are summarised in Table 6, including a payback period calculation.

Table 6 summarised results of life cycle costing of reusable cup compared to disposable over 3 years

	Total cost of disposable cup (\$)	Total cost of reusable cup (\$)	Pay back period (no. of uses of reusable cup)
Including end-of-life costs:	113.60	18.34	184
Excluding end-of-life costs:	109.50	18.33	184

Table 7 Data used to in life cycle costing comparing reusable cup to disposable over three years

Cost of reusable 12oz cup (\$)	Cost of disposable 12oz cup (\$)	Mass of reusable cup (kg)	Mass of disposable cup (kg)	Garbage disposal cost per tonne (\$)	Recycling collection cost per tonne (\$)	Avg. ACT water price (\$/kL)
(keepcup.com, 2015)	(hospitalitywholesale.com, 2015)	(keepcup.com, 2015)	(hospitalitywholesale.com, 2015)	(Sustainability Victoria, 2014)	(Sustainability Victoria, 2014)	(Iconwater.com.au, 2015)
16	0.1	0.092	0.018	208	111	3.91
ACT electricity price (\$/kWh)	Water used per cup in dishwasher (L)	Energy used per cup in dishwasher (KWh)	Cost of washing per cup (\$)	Cost of reusable end of life per cup (\$)	Cost of disposable end of life per cup (\$)	
(Originenergy.com.au, 2015)	(Lockrey, 2011)	(Lockrey, 2011)				
0.157	0.228571429	0.007857143	0.002127286	0.010212	0.003744	

The results are given including and excluding end of life costs as a consumer does not directly pay for disposal; however it still has a cost associated with it. It is clear that the reusable cup is by far the most cost effective option with a more than 80% reduction in cost. The payback period was quite long considering it would take more than 6 months of daily coffee purchasing to start making a saving. When compared to the results of the energy break even calculation,

the number of uses to break even in energy is less than 10% that of cost. It is worth noting that this costing assumes the saving of the wholesale price is directly passed on to the coffee buyer, which may not always be the case and would affect any payback period.

7. Dynamics and control

From the previous sections it is obvious that reusable cups, present a more sustainable cost and energy efficient alternative to disposable coffee cups. From the qualitative analysis it also became apparent that coffee buyers expressed some support for a system in which only reusable cups may be used to purchase coffee, however drawbacks were also apparent. Due to this we now analyse a hypothetical café as a system, which is switching to reusable cups. The system is analysed using the Systems Archetype approach outlined by in article by Braun in 2001.

7.1 Application of limits to growth systems archetype to café switching to reusable cups

For the analysis we assume the café has decided for environmental reasons to switch to only accepting reusable cups, and will do so completely in a specific amount of time. To encourage the use of the cups a marketing campaign is run and financial incentives are given to those who use reusable cups, with the goal being that effectively 100% of their clientele are using reusable cups by the end of the promotion period, so that they can switch to them permanently.

There are many different potential System Archetypes which this type of system could potentially fall under in a real setting, in this simplified hypothetical though it most closely aligns with Limits to growth archetype. This is due to the likelihood of the number of customers per day using reusable cups growing initially and then reversing as the limits on growth start to become prevalent, leading to diminishing returns on efforts to increase them. The prescriptive action for this type of system outlined by Braun is to focus on removing the limits rather than boosting the driving factors, and to identify links between the growth and limiting processes to manage the balance between the two (Braun, 2002).

We identify the growth factors as being the financial incentives and the marketing campaign, and the main limits being reduced customer satisfaction from the extended wait times from the challenges of making coffee using reusable cups outlined in the qualitative section. These are linked in that as more people respond to the growth engines the more reusable cups there are that flood the coffee making process not yet equipped for this inrush, thus crippling the system. These processes can be best managed by avoiding large growth engines initially and instead provide small incentives to use reusable cups, whilst implementing strategies derived from the qualitative analysis. Such as creating a standard type of cup that is accepted, and evolving ways to stack and write on the cup. As the limiting factors diminish so the growth processes can

increase allowing steady growth until the switch over period is finished at which point it can be decided whether to switch permanently or continue with the current system.

8. Time factors

A time factors analysis is done using a simplified PERT chart method, in an attempt to address concerns raised in the qualitative analysis, as well as respond in a different way to the limiting growth factors of a hypothetical café switching reusable cups identified in section 7.1.

8.1 Application of PERT chart to reusable cup coffee order system

From the qualitative analysis it was clear many takeaway coffee buyers had concerns about the inconvenience of remembering and washing a reusable cup. Although this is a defining aspect of a reusable method it should be less inconvenient if this process does not have to happen at home or outside of the café the coffee is brought from. Similarly, the main limiting factor in the hypothetical café adopting reusable cups in the dynamics and control section was reduced customer satisfaction due to increased wait times. This system is described in a PERT chart in Fig. 4 (1).

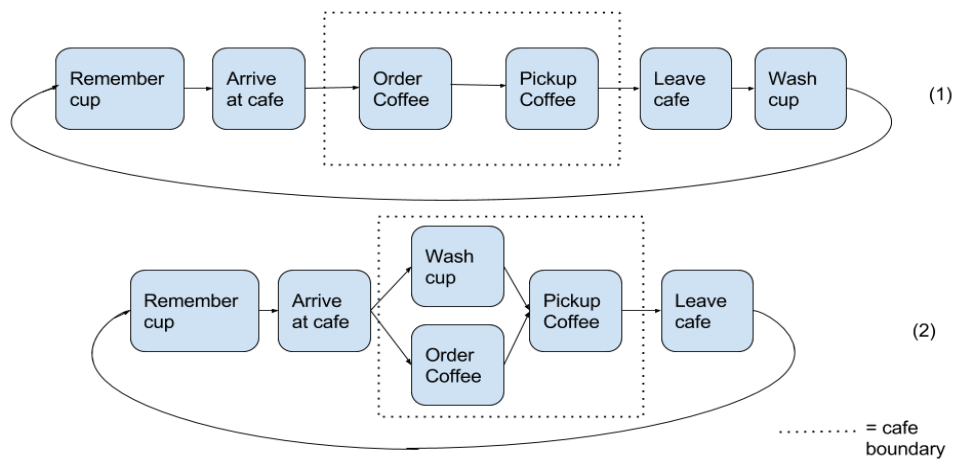


Figure 4 Standard reusable cup system shown indicated by (1), system including dishwasher in café in (2)

Improvements on these issues may be made by including an efficient dishwasher in the café. Rather than being linear, the critical path in Fig.4 (2) will be through either the cup wash or the ordering depending on the length of wait time. However this additional phase allows customers to make use of the time spent waiting more efficiently by completing a task they would have to do outside of the café. This should decrease the inconvenience of a reusable cup especially if more than one coffee is wanted per day.

Conclusions

From the qualitative and material factors it was found that there are significant environmental impacts of using disposable hot beverage cups, and that at the current levels of material technology disposable cups cannot be manufactured to be much more sustainable, however reusable cups as an alternative have a lot less of an environmental impact. The qualitative analysis indicated support for the use of reusable cups in coffee buyers, and baristas with potential drawbacks also present. The energy and cost factors analysis indicated that a reusable cup is a lot more energy and cost efficient over its lifetime than a disposable. A human factors analysis found risk of injury could be mitigated if glass reusable cups are not used in case of breakage. From the dynamics and control and time factors sections it was seen that a café adopting a reusable only method would face difficulties and that these could be lessened through careful management, and striving to decrease wait times and inconvenience of customers. As such it recommended plastic reusable coffee cups should be adopted wherever possible, so long as consistent reuse is maintained, in order to significantly reduce environmental impacts.

References

- Australian National Audit Office, (2001). Life-cycle costing better practice guide. Canberra: Commonwealth of Australia.
- Braun, W. (2002). The System Archetypes. 1st ed.
- Hakkinen, T. and Vares, S. (2010). Environmental impacts of disposable cups with special focus on the effect of material choices and end of life. *Journal of Cleaner Production*, 18(14), pp.1458-1463.
- Hocking, M. (1994). Reusable and disposable cups: An energy-based evaluation. *Environmental Management*, 18(6), pp.889-899.
- hospitalitywholesale.com, (2015). Single Wall Grow Cup 12oz. [online] Hospitality Products. Available at: <https://www.hospitalitywholesale.com.au/shop/c/packaging/packaging/retail-food-service-bags/single-wall-grow-cup-12oz/> [Accessed 12 Oct. 2015].
- Iconwater.com.au, (2015). ACT residential water prices. [online] Available at: <https://www.iconwater.com.au/My-Home/My-account/Pricing-and-your-Customer-Contract/Residential-water-prices.aspx> [Accessed 12 Oct. 2015].
- keepcup.com, (2015). Store: Diablo M size. [online] Available at: <http://au.keepcup.com/featured/diablo-512.html> [Accessed 12 Oct. 2015].
- Lockrey, S. (2011). The Ecocraze, a Case Study: Negotiating a Greener Product Design Landscape. *Design Principles and Practices: An International Journal*
- Originenergy.com.au, (2015). Energy Prices - Origin Energy. [online] Available at: <https://www.originenergy.com.au/for-home/electricity-and-gas/plans/energy-price-fact-sheets.html> [Accessed 12 Oct. 2015].
- Starbucks Coffee Company/ Alliance for Environmental Innovation, (2000). Report of the Starbucks Coffee Company/ Alliance for Environmental Innovation Joint Task Force.
- Sustainability Victoria, (2014). Annual Report 2013 & 14. Melbourne: State of Victoria.
- Worksafe Victoria, (2006). *Officewise A guide to health & safety in the office*. Melbourne: Victorian Government.
- Xie, M., Qiao, Q., Sun, Q. and Zhang, L. (2012). Life cycle assessment of composite packaging waste management a Chinese case study on aseptic packaging. *Int J Life Cycle Assess*, 18(3), pp.626-635.

Appendices

Appendix A

Appendix A.1 Copy of coffee buyers online survey

Reusable coffee containers: survey of takeaway coffee buyers

This is a survey about reusable takeaway coffee cups, like those pictured below. They are made to be taken to the cafe you want to get takeaway coffee from, and then washed and used again (you probably already know this but just so we're on the same page). The results of this survey are anonymous and will be used in an ANU systems engineering assignment, analyzing takeaway coffee containers as a system.

*Required



1. Do you buy takeaway coffee? *

Mark only one oval.

- yes
- no

2. Do you believe there are benefits of using reusable takeaway coffee containers?

Mark only one oval.

- a lot of benefits
- some benefits
- no benefits

3. What were those benefits? (if any)

4. Do you believe there are negatives of using reusable takeaway coffee containers?

Mark only one oval.

- a lot of negatives
- some negatives
- no negatives

5. What were those negatives? (if any)

6. Would you use a reusable takeaway cup to buy coffee?

Mark only one oval.

- I already do
- yes definitely
- its likely
- its not likely
- definitely not

7. Imagine a world where you can now only buy takeaway coffee using a reusable cup you brought to the cafe, how do you react? *

Mark only one oval.

- its a great idea
- its an ok idea
- its a bad idea
- its a terrible idea

8. If you thought of any positives about this idea, what are they?

9. If you thought of any negatives about this idea, what are they?

10. Do you have any other thoughts on reusable coffee cups, that you haven't already said?

Appendix A.2 results of coffee users survey

Table 1 results of coffee users survey

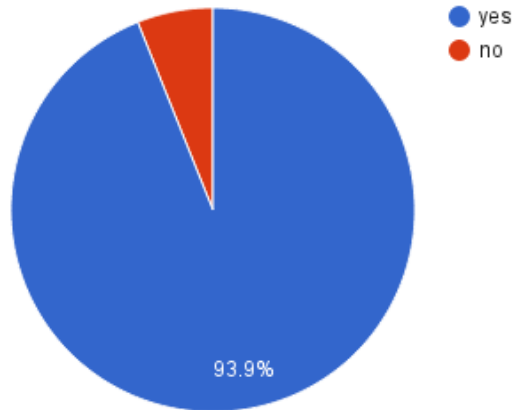
Timestamp	Q1. Do you buy takeaway coffee?	Q2. Do you believe there are benefits of using reusable takeaway coffee containers?	Q3. What were those benefits? (if any)	Q4. Do you believe there are negatives of using reusable takeaway coffee containers?	Q5. What were those negatives? (if any)
01/10/2015 23:11:57	yes	a lot of benefits	reduces costs for the store which would (hopefully) lead to cheaper coffee. Also reduces embodied energy of your coffee and hence reducing your environmental impact	some negatives	you have to carry it around with you everywhere and clean it everyday
01/10/2015 23:15:53	yes	a lot of benefits	better for the environment, you can use the cup for other things	some negatives	you have to pay for the cup, you also have to wash it and you also have to remember it
01/10/2015 23:39:21	yes	some benefits	Less waste	some negatives	You can forget your cup, expensive initially
01/10/2015 23:39:32	yes	some benefits	Less environmental impact, potential for a swagged out takeaway container	some negatives	Annoying to carry around everywhere
02/10/2015 08:28:55	yes	a lot of benefits	Less rubbish	some negatives	Possible contamination issues is barista not trained/careful
02/10/2015 09:33:47	yes	some benefits	less rubbish	some negatives	not all coffee shops will accomodate
02/10/2015 09:34:22	yes	some benefits	benefits the environment	some negatives	you have to remember to bring it
02/10/2015 09:45:09	yes	a lot of benefits	you can use your cup at a multitude of cafes, plus it's better for the environment	some negatives	you have to remember to take it...
02/10/2015 09:49:02	yes	a lot of benefits		no negatives	
02/10/2015 09:50:10	yes	some benefits	Environmental	some negatives	Inconvenience
02/10/2015 09:58:06	yes	some benefits	Less waste	some negatives	Lack of cleanliness, not as convenient (can't just throw away the container after use)
02/10/2015 10:17:59	yes	a lot of benefits	Less rubbish, personalised cups	some negatives	More frustrating for cafes
02/10/2015 10:34:49	yes	some benefits	Less waste	some negatives	Forgetting it and needing to purchase another!
02/10/2015 11:07:12	yes	a lot of benefits	less wasteful, uses less plastic in the long run	some negatives	wash the cup, have to remember it
02/10/2015 11:52:19	yes	some benefits	Helping the environment, less waste	some negatives	Have to remember to carry around the reusable container
02/10/2015 14:50:56	yes	some benefits	less waste	some negatives	could be inconvenient at times
02/10/2015 14:53:00	yes	some benefits	Save on disposable cups	some negatives	sticky after use.
02/10/2015 16:26:39	no	a lot of benefits	less environmental damage	some negatives	
02/10/2015 16:46:38	no	a lot of benefits	You get a cooler looking cup	no negatives	
02/10/2015 16:47:45	yes	a lot of benefits	Less waste	some negatives	if you are lazy and don't reuse you're just buying a different kind of waste, which most likely you'll keep buying have heaps lying around the house and throw them out eventually too.
02/10/2015 16:55:32	yes	some benefits	Saving the planet	some negatives	Having to wash it
02/10/2015 18:45:29	yes	a lot of benefits		some negatives	Can be inconvenient
05/10/2015 16:33:18	yes	some benefits	Better for the environment, they look cute	some negatives	I have to remember to bring it, then carry it around all day
05/10/2015 16:40:07	yes	some benefits		some negatives	
05/10/2015 16:48:59	yes	a lot of benefits	Its environmentally friendly to reuse cups. So much waste is made through disposable ones.	some negatives	Carrying around a coffee cup all day, also one may not have access to cleaning facilities meaning you'd be carrying around a gross coffee cup all day
05/10/2015 17:02:44	yes	a lot of benefits	Uses less resources	some negatives	Could contain harmful materials
05/10/2015 17:38:21	yes	a lot of benefits	Less garbage	some negatives	Reuseable containers maybe harder to biodegrade
05/10/2015 17:53:09	yes	no benefits		some negatives	Effort
05/10/2015 17:58:50	yes	a lot of benefits	reduction of paper cup waste and amount of landfill	some negatives	they are usually made out of unsustainable plastic and require more washing up using water in times of drought
05/10/2015 18:01:56	yes	a lot of benefits	environmental, cost	some negatives	initial cost of purchase, sanitary concern - your own cup may not have the same standard of cleanliness than a cafe's
05/10/2015 18:57:10	yes	some benefits	Good for the environment	some negatives	The plastic might be bad for the environment
05/10/2015 19:52:34	yes	a lot of benefits	Less waste	some negatives	
08/10/2015 07:57:10	yes	no benefits		some negatives	You have to carry a large non-tessellating object with you that becomes unhygienic once used

Timestamp	Q6. Would you use a reusable takeaway cup to buy coffee?	Q7. Imagine a world where you can now only buy takeaway coffee using a reusable cup you brought to the cafe, how do you react?	Q8. If you thought of any positives about this idea, what are they?	Q9. If you thought of any negatives about this idea, what are they?	Q10. Do you have any other thoughts on reusable coffee cups, that you haven't already said?
01/10/2015 23:11:57	its likely	its a great idea	cheaper coffee, reduced environmental impact	have to lug the cup around with you all day and clean the cup	
01/10/2015 23:15:53	its likely	its an ok idea	a lot less waste being produced, possibly cheaper coffee as shop doesn't have to pay for cups	not everyone could afford the cups! how can they drink coffee	
01/10/2015 23:39:21	its not likely	its a bad idea		I might not be able to buy coffee	
01/10/2015 23:39:32	its not likely	its an ok idea	Less wasteful	Inconvenient	
02/10/2015 08:28:55	its likely	its a great idea			
02/10/2015 09:33:47	its likely	its a great idea	again, less rubbish	Forgetfulness	
02/10/2015 09:34:22	its likely	its an ok idea	there would be so much less waste	you could accidentally leave the cup at home	
02/10/2015 09:45:09	its likely	its an ok idea	just like the plastic bag ban, people will adjust	Can I still get my coffee if I forget my cup?!?! I'd probably end up buying a million reusable ones	
02/10/2015 09:49:02	its likely	its a great idea			
02/10/2015 09:50:10	its not likely	its a bad idea			
02/10/2015 09:58:08	yes definite	its a great idea	Less waste, less cost for business, personal touch - bringing your own mug/container would be a good way to create personal attachment to the cafe/brand	Inconsistency with sizing could negatively affect inventory management, also most people don't own cups that are convenient to carry around (with lids) and don't want to wash their own cups, also store bought coffee carry containers usually aren't very good	Maybe a system where the cafe provides the initial cup (to ensure consistent sizing) for a fee and then the patron brings back the original cup to save money on their next visits? So the people who like to throw out their cup and not wash them could do so (at their expense) and the environmentally/financially conscious people can wash and bring back the original cup for a discount. Being able to use insulated coffee cups that could double as a thermos and stay hot for a long time would be useful in colder climates.
02/10/2015 10:17:59	its likely	its an ok idea	No rubbish from disposables	If you forget your cup, you're outta luck	Theyre nice
02/10/2015 10:34:49	its not likely	its an ok idea			
02/10/2015 11:07:12	its likely	its an ok idea	the cafe could sell cheaper coffee because they dont have to pay for cups	being forced to buy the cup	
02/10/2015 11:52:19	its likely	its a great idea	a lot less waste	a lot of people will complain	how much will they cost?
02/10/2015 14:50:56	its likely	its an ok idea	its much more sustainable	you might forget your cup, or have to pay more money for cups	
02/10/2015 14:53:00	its likely	its an ok idea	Less paper usage	sticky after use. No std size	Improved lids to stop leakage. Standardise sizes at time of reusable mug creation.
02/10/2015 16:26:39	its likely	its a great idea	no wastage from throwing away disposable cups	people not getting coffee if they forget theirs	
02/10/2015 16:46:38	its not likely	its a bad idea		Costs more	
02/10/2015 16:47:45	its not likely	its an ok idea	Stated above	Stated above	Na
02/10/2015 16:55:32	its likely	its an ok idea	Less paper being used	People might not wash them and then have to wait for the barista to wash it and it will take more time.	The glass ones could break
02/10/2015 18:45:29	yes definite	its a great idea	Better for the environment	purely inconvenience and potential additional cost. Takeaway coffee in Australia is ready so expensive.	N/A
05/10/2015 16:33:18	its likely	its an ok idea	We'd all get used to it pretty quickly. It might reduce prices of coffee?	What if I forget my cup!	-
05/10/2015 16:40:07	its not likely	its a terrible idea	limiting customers?		
05/10/2015 16:48:59	its likely	its an ok idea	Cleaner, nicer and more personal	A forgetful person would constantly need to purchase a new coffee cup everytime they ordered a coffee, potentially resulting in more waste?	It would also be a burden for some coffee shops needing to supply these coffee cups in order to keep business going. Also, it would be a terrible idea in a touristy area. Tourists should not expect to buy a coffee cup for a one off thing.
05/10/2015 17:02:44	its likely	its an ok idea			
05/10/2015 17:38:21	its likely	its an ok idea	Less cups disposed	those forgetting their cups would be angry	sizing issues Is there generic sizes to charge for the amount of coffee?
05/10/2015 17:53:09	definitely n	its an ok idea	Environmentally friendly		It's a lot of effort to do in a world where it is normal to not use reusable cups. If it was standard practice, it would be normal and would maybe not seem like I was going out of my way.
05/10/2015 17:58:50	I already do	its a great idea	great for reducing waste!	sometimes they leak and everyone is required to carry a bag to carry one around	They need to design better non-leakable containers, or provide more places for washing them on campus
05/10/2015 18:01:56	its likely	its a bad idea	environmental benefits	I rarely buy takeaway coffee, but when I do it is because of convenience and often an unplanned purchase. So, having to BYO a coffee cup each time would be inconvenient.	It is a good idea to have the option of BYO takeaway cups, but as a choice option. There are incentives in place like at some cafes you get a discount if you BYO your own cup.
05/10/2015 18:57:10	its likely	its an ok idea	Environmental benefits, reduces littering	Can't get coffee if you forget your cup	It would be annoying if you wanted multiple coffees in a day as you'd have to clean the cup. Also you'd have to carry a potentially wet and dirty cup in a bag - might leak and damage other items.
05/10/2015 19:52:34	its likely	its an ok idea	Less waste, lower prices as shops don't have to purchase coffee cups cobatantly	Having to carry the coffee cup with you everywhere	Collapsible ones would be good so they take up less soace
08/10/2015 07:57:10	its not likely	its a terrible idea		People will not recycle them. People will still dispose of them, except now if people don't recycle them they will not rapidly disintegrate in the environment like waxed paper cups do	

Appendix A.3 Results of analysis of users survey data

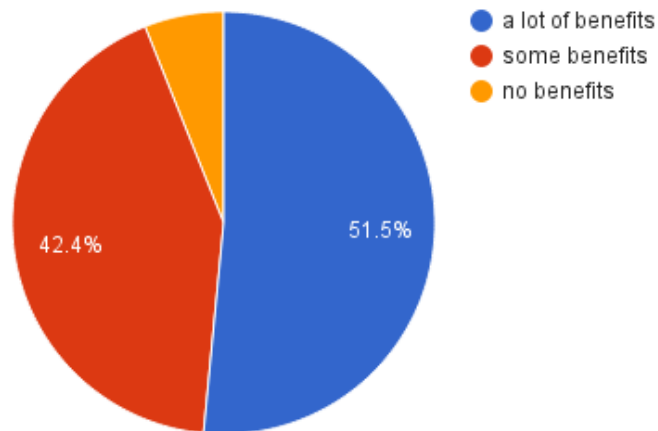
Q1:

Count of "Do you buy takeaway coffee?"



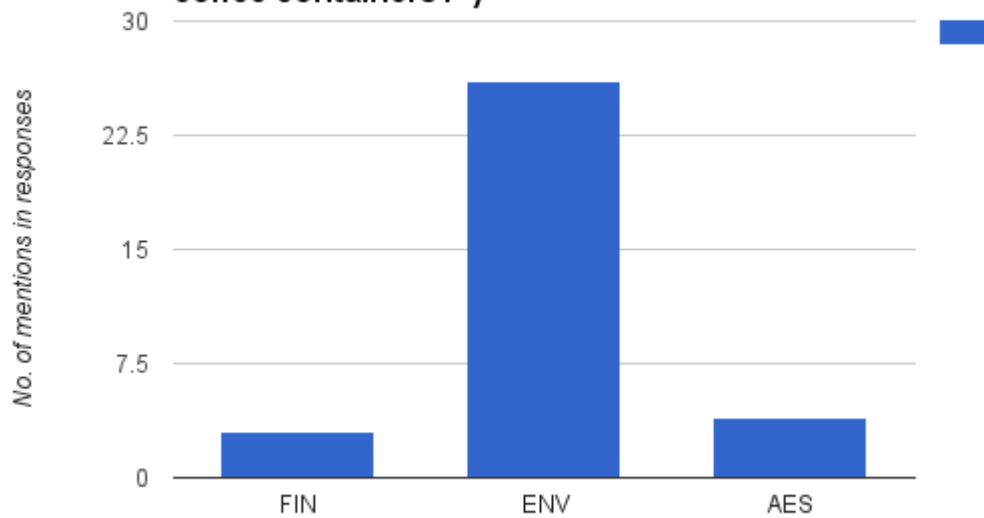
Q2:

Count of "Do you believe there are benefits of using reusable takeaway coffee containers?"



Q3:

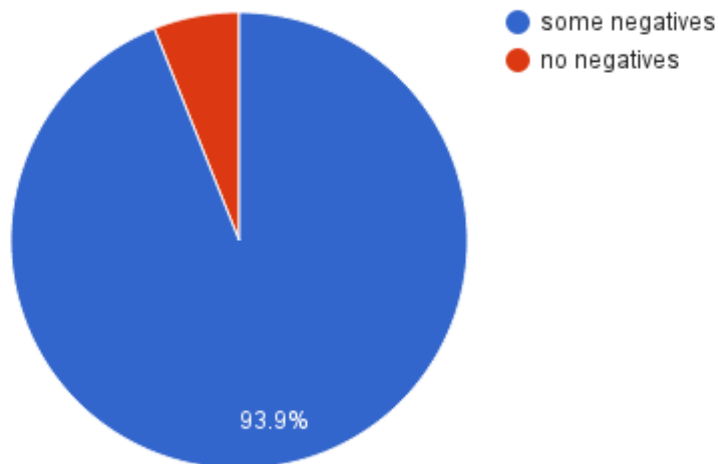
Frequency of topics raised (Q3. "Do you believe there are benefits of using reusable takeaway coffee containers?")



Q3 Code	Q3 Key
ENV	Environmental (less waste/pollution)
FIN	Financial (savings from cafe not buying cups)
AES	Aesthetic (better looking cup)

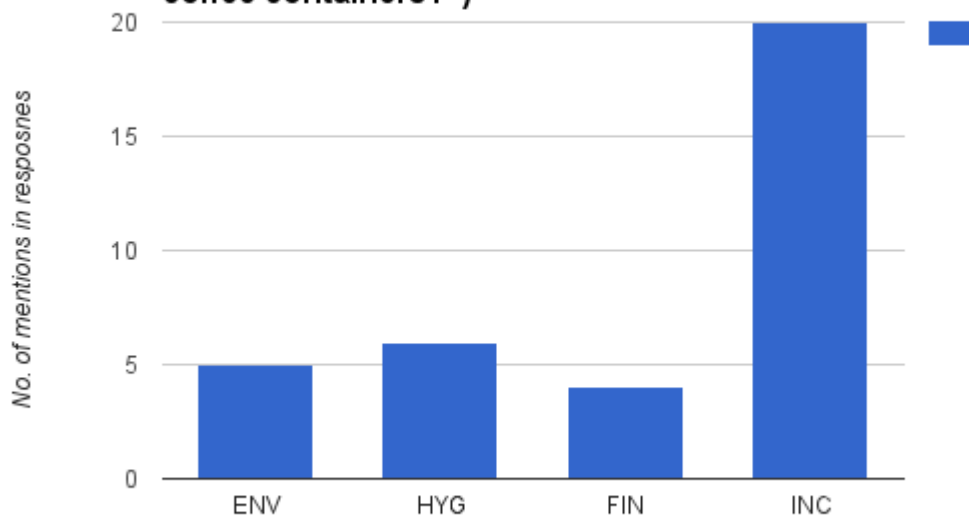
Q4:

Count of "Do you believe there are negatives of using reusable takeaway coffee containers?"



Q5:

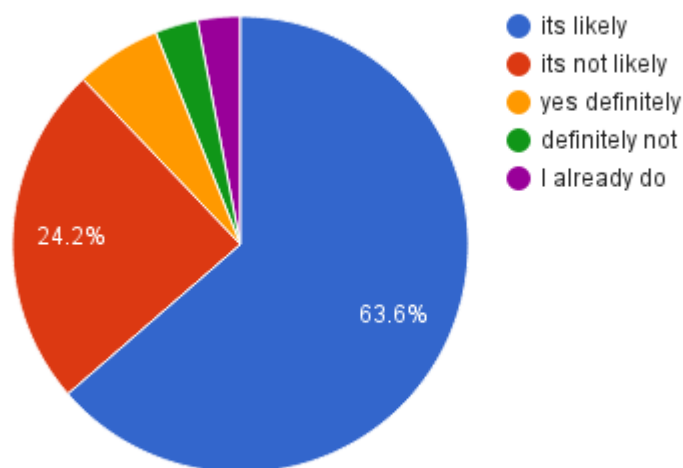
Frequency of topics raised (Q5. "Do you believe there are negatives of using reusable takeaway coffee containers?")



Q5 Code	Q5 Key
INC	Inconvenience (washing cup, remembering it, carrying it, coffee shop incompatibility)
HYG	Hygiene (if not cleaned, cup becomes unsafe/dirty)
ENV	Environmental (could produce more waste, dangerous chemicals in plastic, energy used to clean)
FIN	Financial (purchase cost of cup)

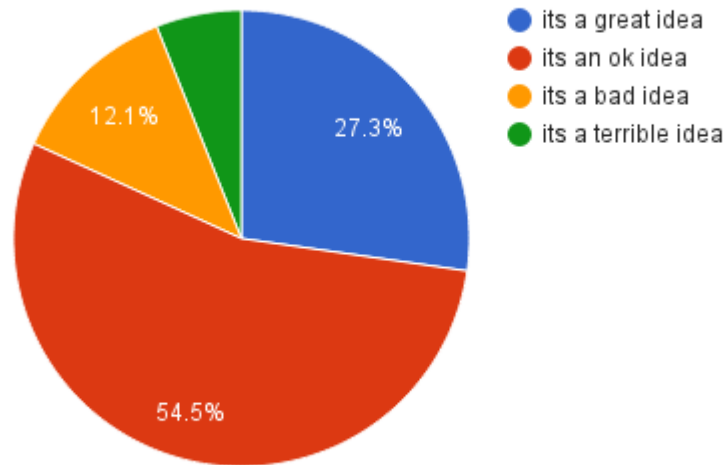
Q6:

Count of "Would you use a reusable takeaway cup to buy coffee?"



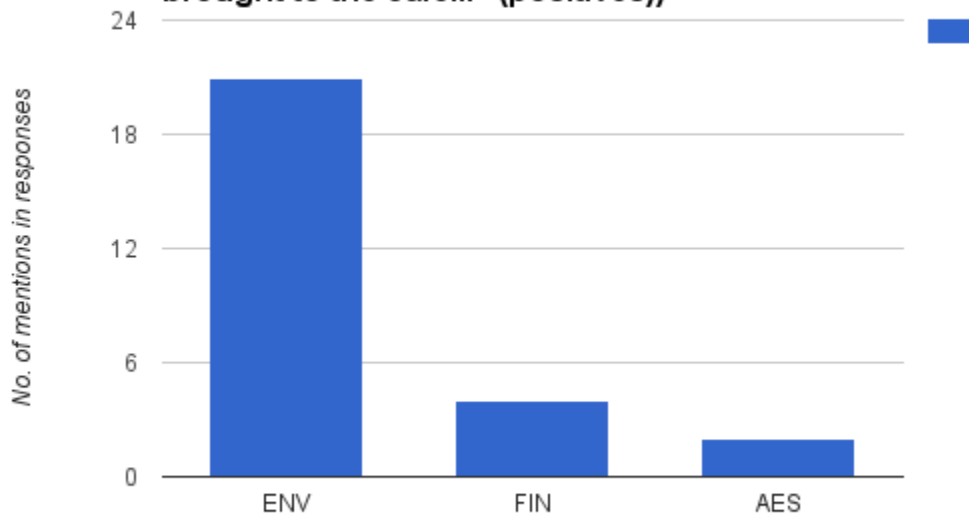
Q7:

Count of "Imagine a world where you can now only buy takeaway coffee using a reusable cup you brought to the cafe, how do you react?"



Q8:

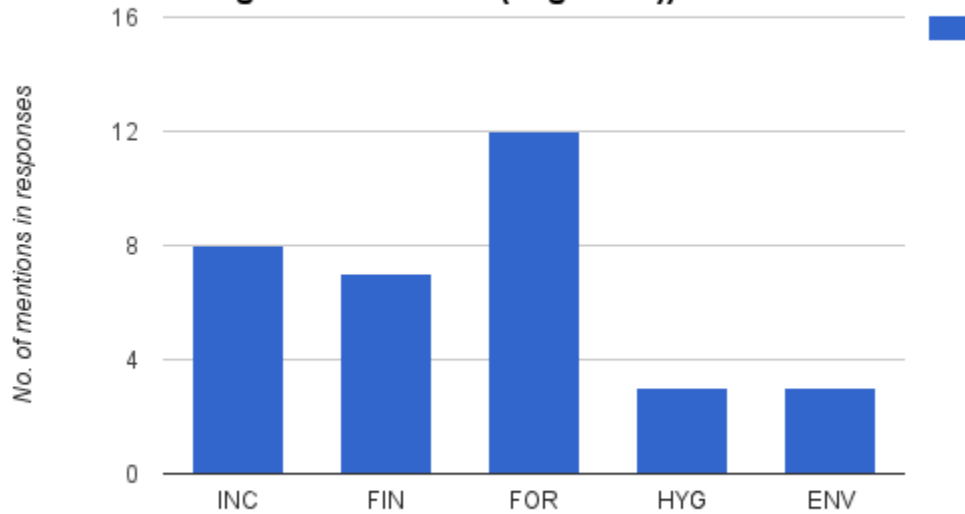
Frequency of topics raised (Q8. "... you can only buy takeaway coffee using a reusable cup you brought to the cafe..." (positives))



Q8 Code	Q8 Key
ENV	Environmental (less waste/polltuion)
FIN	Financial (savings from cafe not buying cups)
AES	Aesthetic (better/more personal looking cup)

Q9:

Frequency of topics raised (Q9. "... you can only buy takeaway coffee using a reusable cup you brought to the cafe..." (negatives))



Q9 Code	Q9 Key
INC	General Inconvenience (washing cup, remembering it, carrying it, coffee shop incompatibility, lack size standard)
HYG	Hygiene (if not cleaned, cup becomes unsafe/dirty)
ENV	Environmental (could produce more waste)
FIN	Financial (forced purchase cost of cup to buy coffee)
FOR	Forgetting cup (not being able to buy coffee as result)

Appendix B

Appendix B.1 Copy of coffee makers interview survey

Reusable coffee containers: survey of coffee makers (interview questions)

1. What impact if any does a reusable cup have when you're making coffee?

Prompts: wait times, ease of making coffee, how cups might stack, health and safety

2. If everyone only used reusable cups, what would be the advantages and disadvantages if any?

3. In general, what is your opinion on reusable cups and why?

4. Any other thoughts/notes on topic

Appendix B.2 Results of coffee makers survey

Table 1 notes from interview of coffee makers

Timestamp	What impact if any does a reusable cup have when you're making coffee?	If everyone only used reusable cups, what would be the advantages and disadvantages if any?	In general, what is your opinion on reusable cups and why?	Any other thoughts/notes on topic
<p>02/10/2015 14:57:38 (Little Pickle Café)</p>	<ul style="list-style-type: none"> - size of cup is important but not crucial (mainly to estimate size) - oversized cups slow down process (cup the size of mug is good) - for regular customers, barista is able to identify the type of coffee to make based on cup appearance -risk of injury the same as paper cups 	<ul style="list-style-type: none"> - there would be a lot of empty cups waiting to be used taking up counter space (cafe was small and paper cups can be neatly stacked on top of coffee machine) - stacking cups is not possible if different shapes, and thickness of reusable would make them take up more space even if stacked - there would be cost savings by not having to buy cups 	<ul style="list-style-type: none"> - good for the environment, less wasteful - people should use them 	<ul style="list-style-type: none"> - dirty or broken cups are not accepted by cafe
<p>03/10/2015 15:02:07 (The Coffee Grounds)</p>	<ul style="list-style-type: none"> - no problem in terms of how coffee is made - different sized cups don't slow things down too much (use something else to pour shot into cup if needed) - have to match the brought in cup to a standard paper size one which isnt always accurate - does not impact safety 	<ul style="list-style-type: none"> - cost savings of no longer having to buy cups - have to create new method of labelling which order is with each cup, as previously labels would be written on paper cup (suggested that receipt printer could print order then attach it to cup) 	<ul style="list-style-type: none"> - better for the environment - would encourage people to use them - any difficulties they create in making coffee could be easily managed 	<ul style="list-style-type: none"> - store currently gives 50c discount to everyone who brings in reusable cup

Appendix C System boundary used in comparative LCA

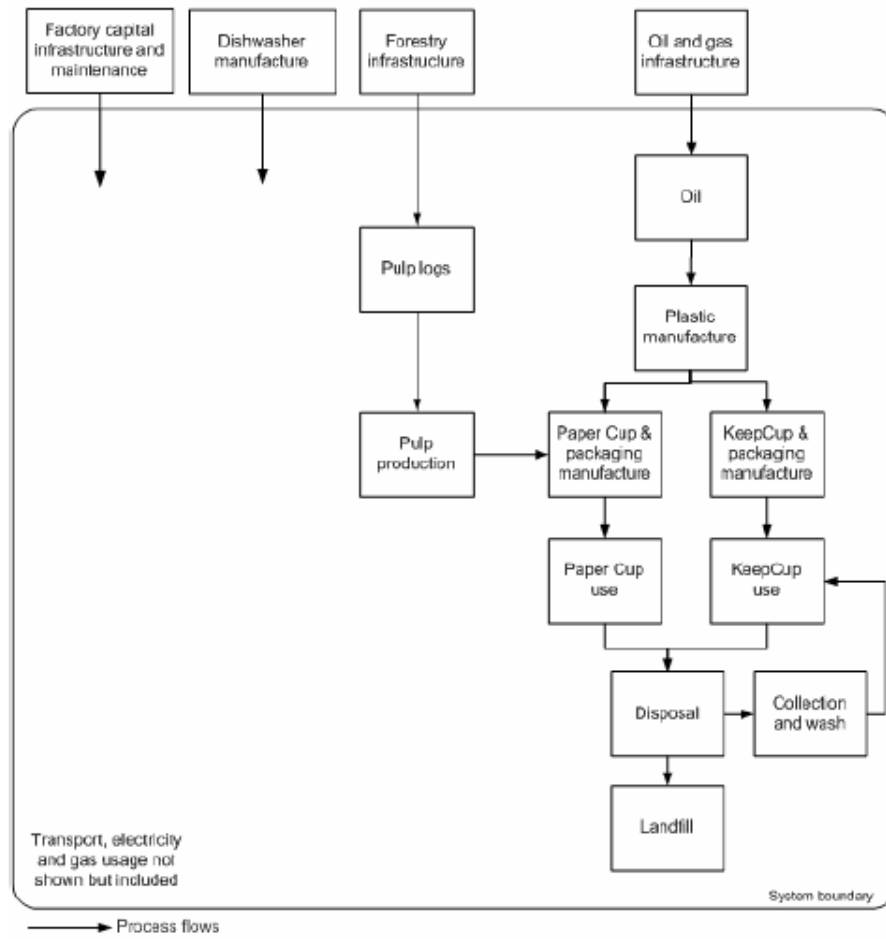


Figure 1 System boundary used in comparative LCA of reusable cup and paper cup over 1 year (Lockrey, 2011)