Go Blue Box vs. Compostable Boxes

Life Cycle Assessment

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The purpose of this project was to perform a life cycle assessment of two kinds of containers used for take-out services at the University of Michigan Union, sugarcane-based (bagasse) compostable boxes and reusable polypropylene-based Go Blue Boxes. We assumed a functional unit of 360 uses, which represented the life of 1.01 Go Blue Boxes (accounting for a 1% breakage rate) and 360 compostable boxes. After comparing energy consumption, water consumption, greenhouse gas emissions and costs, it was overwhelmingly clear that the reusable Go Blue Boxes are the better option. Taking both the environmental and financial aspects of our analysis into account, our recommendation is that the University of Michigan Union expand the Go Blue Box program and continue to grow its use as the take-out container of choice.

Overview

Go Blue Box is a start-up student company at the University of Michigan that produces a reusable polypropylene-based carryout container for food items (see **Exhibit 1**). As a student start-up, Go Blue Box decided to pilot its product with the Michigan Union, which is currently using a compostable sugarcane-based to-go container (see **Exhibit 1**). The basic approach is that students sign up to be a part of the program, use the Go Blue Box container to take out food from the Union and then are expected to return it in order to take a new box on their next visit. The Union then washes the returned containers, and the cycle continues until a box is broken or has been fully used, i.e. what the company asserts is 360 times (usable life), at which point the box can be recycled. By reusing the containers, the goal is to both save money and benefit the environment. Within the first two months of the Go Blue Box program running at the Union, 2,000 fewer compostable containers were used. So far, approximately half of the Union's carryout customers have adopted the program and the Union is hoping to expand the program. However, in order to do so, the Union would like to understand the full financial and environmental effects of the two options. In addition, Go Blue Box is considering launching its business in the wider Ann Arbor community or in other cities across the country and needs to understand the life cycle to market the benefits of its product.

This project includes life cycle analyses (LCA) of both the Go Blue Box and the compostable box. We chose a functional unit of 360 uses, which represents 1.01 Go Blue Boxes (accounting for a 1% breakage rate) and 360 compostable boxes. The majority of our life cycle analysis was done using data from SimaPro.

Go Blue Box Assessment

As seen in **Exhibit 2,** Go Blue Boxes go through 5 phases: raw material production, manufacturing, use, end of life and transportation between phases. In this project, it was assumed that the Go Blue Box only contains polypropylene, with no other material used in the manufacturing process. Therefore, the only raw material used is Polypropylene resin. The main advantages of polypropylene include it being flexible for shaping, food contact is acceptable, it is resistant to acids and bases, its impact and wear resistances are high and it is cheap. It is also dishwasher safe due to its high melting point (higher than 160°C). For comparison purposes, polyethylene's melting point is around 100°C. However, the disadvantages of polypropylene include it being flammable, poorly resistant to organic solvents and susceptible to degradation by UV and oxidative degrading caused by several metals.

Raw Material Production

To produce polypropylene resin, oil and natural gas need to be extracted, refined and then processed into propylene. Propylene is then polymerized into polypropylene resin using the Zieglar-Natta polymerization process with the use of specific chemicals and catalysts including Titanium Tetrachloride and Aluminum. The process chosen in SimaPro for this process was "PP resin production, per kg."

Manufacturing

Following production of PP resin, the Go Blue Box is formed by an injection molding process. Injection molding is a manufacturing process done by injecting material into a previously defined mold to shape the material. PP resin is melted and then injected into the mold to form the

Go Blue Box. The disadvantage of such a process is that it is highly energy intensive and, depending on the plant location's electricity mix, can result in very high carbon emissions. Other disadvantages include that the initial investment and running costs for this process are high and accurate cost prediction is difficult. By contrast, the advantages of this process include design flexibility, very low losses due to scraps, no finishing of parts, repeatability and low labor requirements. The process chosen in SimaPro was "Polypropylene Injection Molding, per kg." Because this process also includes the raw material production, raw material production data were subtracted from the values to find individual process impacts.

Use Phase

Although the box goes through energy-intensive manufacturing phases, because each Go Blue Box is used 360 times, the main impact of the process is in the use phase. Each box is washed 360 times during its lifetime, which makes the use phase highly water and energy intensive.

End of Life

After 360 uses, Go Blue Boxes go to either landfills or a recycling facility based on the rates that we assumed initially. The high recycling rate is based on the Michigan Union having a robust recycling program.

Transportation

Transportation of raw materials within China was incorporated into our SimaPro analysis. The box is then transported via ocean freighter from Shanghai Port to Long Beach Port in California (10,690 km) and then transported to the producer's headquarters in Houston by truck (approximately 2690 km). From Houston, the boxes are distributed to Ann Arbor using trucks (approximately 2080 km). To account for transportation during the end of life phase, 16 km were added to the movement with truck. The options in SimaPro used were "Bulk carrier ocean, technology mix, 100.000-200.000 dwt GLO" for ocean transport and "Articulated lorry transport, Euro 0, 1, 2, 3, 4 mix, 40 t total weight, 27t max payload" for truck transport. See **Exhibit 3** for transportation routes.

Compostable Box Assessment

As seen in **Exhibit 4**, the compostable to-go boxes, like the Go Blue Boxes, go through 5 phases: raw material production, manufacturing, use, end of life and transportation between the phases. In our project, we assumed that the containers are made entirely of bagasse, a fibrous material that is a byproduct of sugarcane production. Although the soak-proof version of this box is lined with PLA, the non-PLA lined version was used for this assessment. Each compostable box weighs 0.11 lbs. To achieve our functional unit of 360 uses, 360 containers are needed (0.11 lbs/container * 360 containers = 39.6 lbs boxes).

Raw Material Production

The bagasse used to make the compostable boxes comes from sugarcane, so raw material acquisition involves the production of sugarcane. It is worth noting that bagasse is a necessary byproduct of sugarcane production. Therefore, its use does not necessitate additional production of sugarcane. The website for the compostable boxes used in the Union claims that the product is made from 100% renewable and reclaimed resources and that bagasse products are made from a reclaimed resource that would otherwise be burned.[i] However, what the website does not mention is that bagasse is often burned to fuel sugar mills.[ii] Therefore, our project would have been incomplete if we did not appropriately allocate emissions, energy and water use from the raw material phase in our analysis. The process chosen in SimaPro for this phase was "Bagasse, from sugarcane, at sugar refinery/BR S."

Manufacturing

Due to data availability in SimaPro, we modeled the manufacturing phase of the compostable containers after paperboard manufacturing, which is most similar to the actual process of pulping and pressing bagasse. To create the product, wet bagasse is processed, pressed, disinfected, dried into paperboard and processed again into a clamshell shape.[iii] The results indicate that the manufacturing process is both energy and water intensive. However, our assumptions may have overestimated our findings. The process chosen in SimaPro for this phase was "Paperboard container manufacturing," which is US based.

Use Phase

The compostable boxes in the Union are one-use products. Therefore, the use phase for compostable boxes only includes a single use for each container, with no additional inputs into the system.

End of Life

After a single use, the product is sent to either a composting facility or landfill. The product is compostable in commercial compost facilities but, unfortunately, not in your home compost. Based on the existing Michigan Union infrastructure and after speaking with Go Blue Box founder Rich Grousset, we assumed that 10% of the boxes are composted and 90% are sent to landfills.

Transportation

The compostable boxes are manufactured in China and transportation of raw materials within China was incorporated into our SimaPro analysis (we found the distances similar to bagasse production in Brazil, which was the basis of our analysis). The box is then transported via freighter from Gangzhou to Long Beach Port in California (11,942 km) and via truck to Denver, CO (1,656 km). From Denver, the boxes are then transported to Ann Arbor via truck (1,978 km). For transportation in the end of life phase, we added 16 km to truck transportation. The chosen processes for SimaPro were exactly the same as the Go Blue Box. See **Exhibit 5** for transportation routes.

Cost Analysis

The costs of the Go Blue Box and compostable boxes are primarily made up of the purchase price and end of life disposal costs. The major difference in cost makeup occurs during the use phase, where the reusable box incurs costs due to washing, including electricity and water costs incurred by the Michigan Union for the approximately 14.2574 washes needed over the 360 uses. See **Exhibit 6** for a full cost breakdown. This cost analysis assumed no cost for labor washing or allocation of depreciation for the washing machine given that the additional cost would be negligible. However, if the number of washes needed were to increase significantly if the program were to expand those costs could become more material and would need to be included.

The costs for the washing phase were based on the specifications of the Hobart CCS86A (see **Exhibit 7** for a breakdown of water and electricity requirements for this washer model).

The costs used for end of life waste management were those presented in lecture for the City of Ann Arbor for 2002—$121.82 for recycling, $67.50 for landfill and $50.83 for composting. Given that the waste management costs for the University (and thus the Union) are skewed because certain costs are offset through Planet Blue operations, using the Ann Arbor city rates are useful to determine a more realistic cost of the life cycle of both products. However, it should be noted that given the changes in composting services in Ann Arbor with the new program run by WeCare Organics the cost for composting may no longer be correct and all three costs would certainly vary by location if the Go Blue Box program were to be expanded to other cities.

Conclusions: Go Blue Box and Compostable Box Comparison

Exhibit 8 and **Exhibit 9** show the energy consumption, water consumption and greenhouse gas emissions data for 1 Go Blue Box and 360 compostable boxes, respectively. As data suggests, energy consumption, water consumption and greenhouse gas emissions for the Go Blue Box is dominated by the use phase because of the 360 wash per box washing rate. The second most energy consuming process was raw material production, followed by manufacturing. Water consumption in raw material production and manufacturing is negligible compared to the use phase. Regarding greenhouse gas emissions, the second dirtiest process was manufacturing, followed by raw material production. Due to the energy- and water-intensive processes, the transportation and end of life contributed very little to the overall impacts.

On the other hand, bagasse is an all-natural product, so it creates a healthy, nontoxic container for food. However, the product being compostable is does not greatly benefit the lifecycle impact of this product given the lack of commercial composting available at the Michigan Union for it to take advantage of (used a 10% compost rate). In terms of specific impacts, as **Exhibit 10** demonstrates, water use for the product system comes entirely from raw material production and manufacturing. The majority of energy consumption comes from manufacturing, followed by raw material production and transportation. Similarly, the majority of emissions come from manufacturing (although, again, this may be overestimated), followed by raw material production.

Exhibit 10 shows the comparison of Go Blue Box and compostable box with respect to life cycle energy consumption, water consumption and greenhouse gas emissions. Our results show that Go Blue Box was better than the compostable box in all aspects. This was mostly based on the number of boxes required to cover the functional unit. The fact that the compostable box is single use turned out to be an extremely powerful weakness compared to the Go Blue Box with regard to it being environmentally friendly, at least within the context of our study.

The second part of our comparison was to compare the boxes in a one-to-one ratio, assuming the Go Blue Box was never being washed and disposed after each use. So we compared 360 compostable boxes with 360 Go Blue Boxes. In this analysis, Go Blue Box was worse than compostable box in energy consumption and greenhouse gas emission aspects. However, the compostable box needed to consume more water than Go Blue Box as a result of the water-intensive paper production processes.

All of our comparisons suggested that in terms of environmental and financial considerations (with the 360 use per box rate for the Go Blue Box), Go Blue Box is the superior product. It shows that even though the use phase of the Go Blue Box was a lot worse in impacts compared to other phases, it is still very low with respect to the compostable box covering the same functional unit. It continues to also compete on price even when the return rate is lower than ideal and 10 boxes are required.

Regulatory and Other Issues

There are several factors that would affect the results of our LCA if they changed. For example, changes in water or electricity pricing would affect the cost of the use phase for the Go Blue Box. Also, changes in recycling availability would affect the overall environmental impact of the Go Blue Box. If Go Blue Box were to expand into areas that did not accept #5 plastic or if it were compared to a compostable option in a location where robust commercial composting was available, the end of life data for both products would change significantly. In addition, currently the FDA has strict regulations on the recycled content allowed in food packaging. Right now Go Blue Box uses only virgin polypropylene, but if they wanted to use recycled material (see below in strategies for improvement) it would have to comply with these regulations. Other regulatory changes could affect this overall lifecycle assessment, but would not make a significant difference in this comparative study. For example, changes in electricity regulation in both China and the US towards use of cleaner energy standards or changes in pricing for that energy would affect both products equally. Another issue that this study did not investigate in depth, but could be of concern is the potential for plastic leaching Go Blue Box. Polypropylene is not proven to leach chemicals, but with a plastic being reused multiple times this is something that should be considered. Overall, the most important aspect to keep in mind is that for the Go Blue Box to be dominant over other options, the program needs proper marketing strategies to maintain high return rates. If the boxes are not returned and reused, then the cost and environmental impacts increase greatly.

Strategies for Improvement

As a business, Go Blue Box is off to a great start and this study shows how well it does against a non-reusable product. However, as a company looking to grow there are always areas for improvement. It is important that if Go Blue Box wants to expand, they do so into areas with established recycling infrastructure to ensure optimal recycling. As a relatively progressive city when it comes to environmental issues, Ann Arbor is a good barometer for waste management overall in this country. Go Blue Box will likely not find robust commercial composting available in most of the places it is looking to expand, but it might want to specifically target areas where this option is not available to ensure the Go Blue Box continues to stack up from a life cycle perspective. Go Blue Box could continue to improve its environmental and cost impacts by using a product that is comprised of some recycled polypropylene content instead of 100% virgin material. Go Blue Box should also consider expanding its product line with other forms/sizes of plastic takeout containers to raise usage rates.

Appendix
Exhibit 1: Go Blue Box and Compostable Box

The Go Blue Box

The sugarcane-based compostable option

Exhibit 2: Go Blue Box Process Flow Diagram

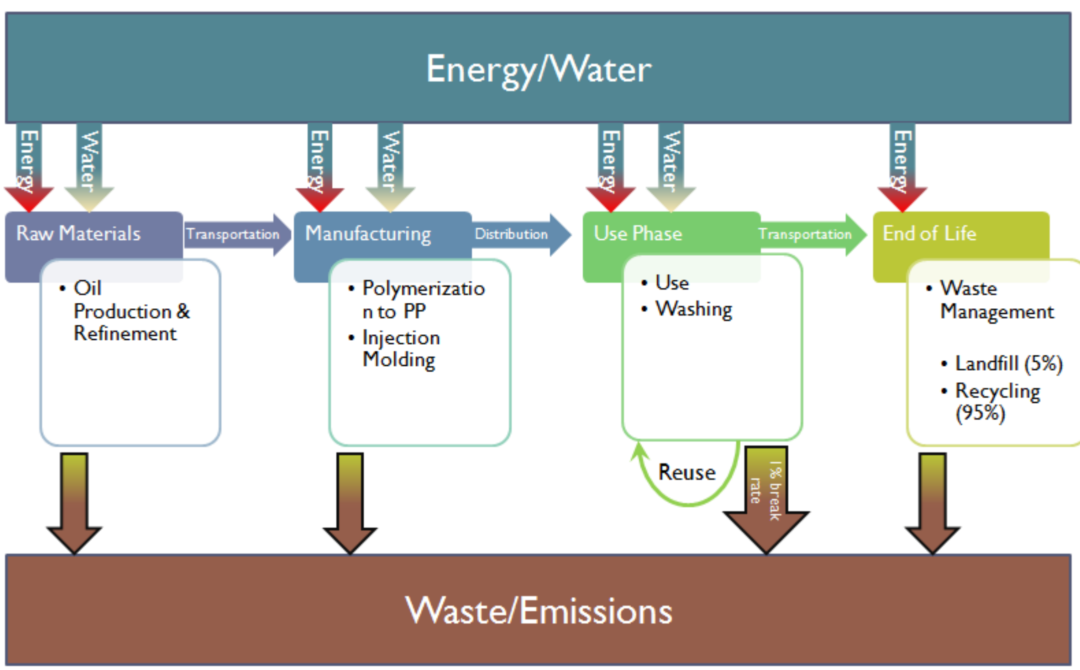
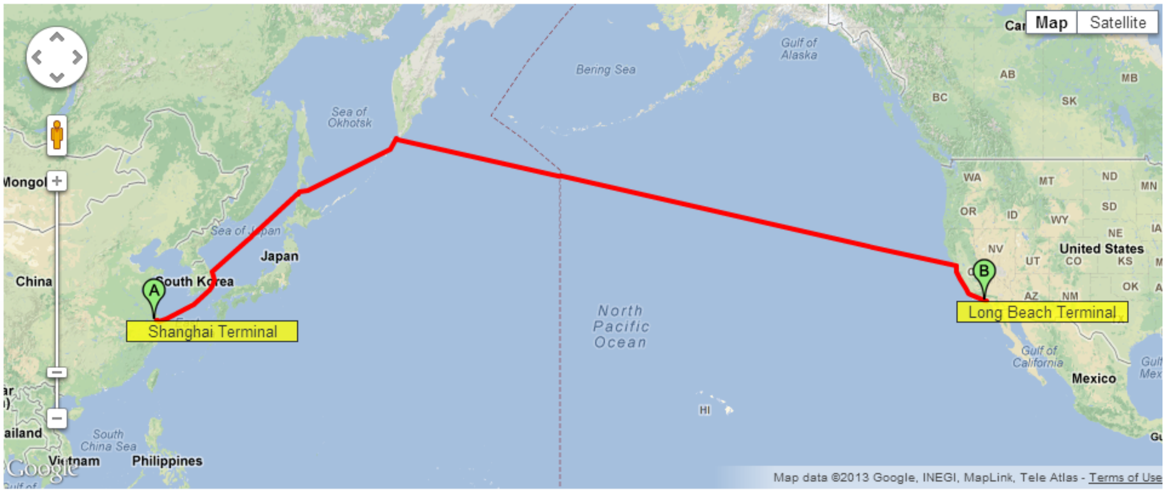
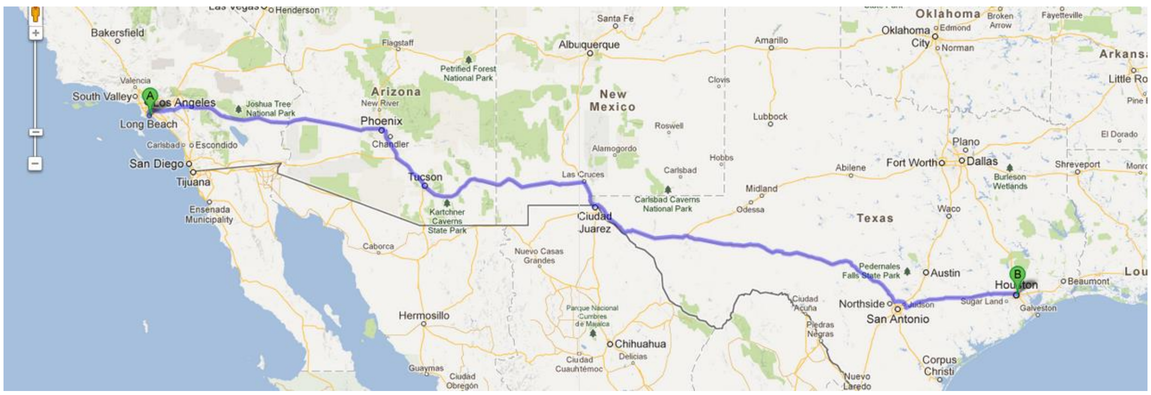


Exhibit 3: Go Blue Box Transportation Roadmap





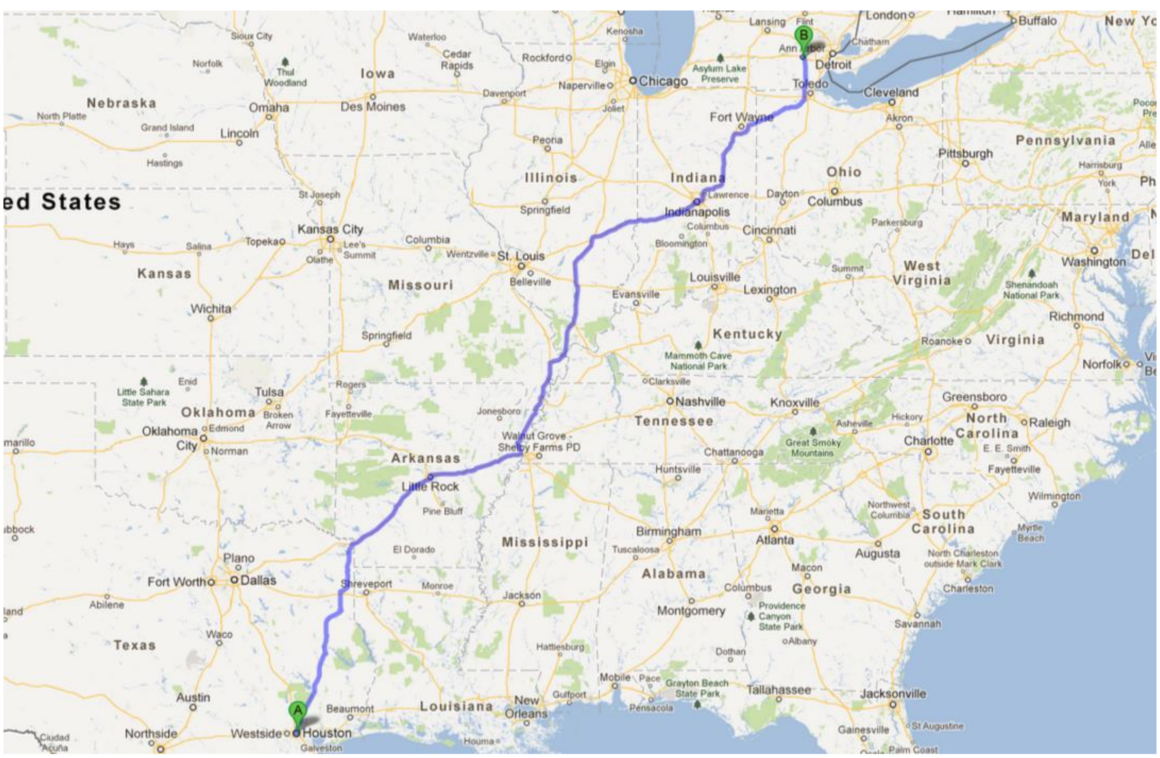


Exhibit 4: Compostable Box Process Flow Diagram

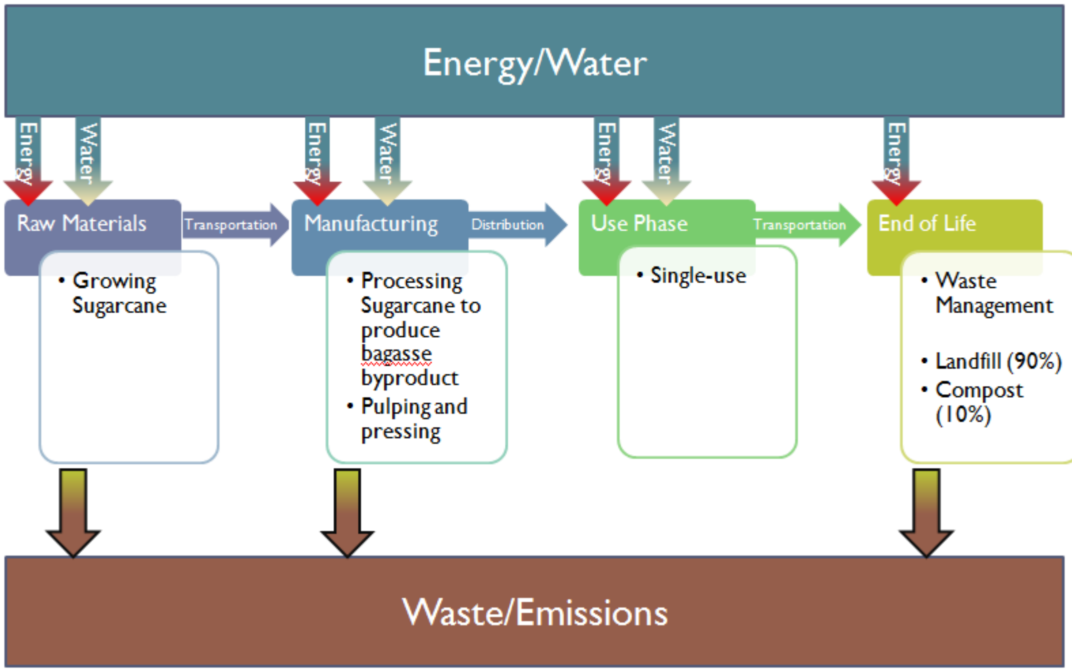


Exhibit 5: Compostable Box Transportation Roadmap

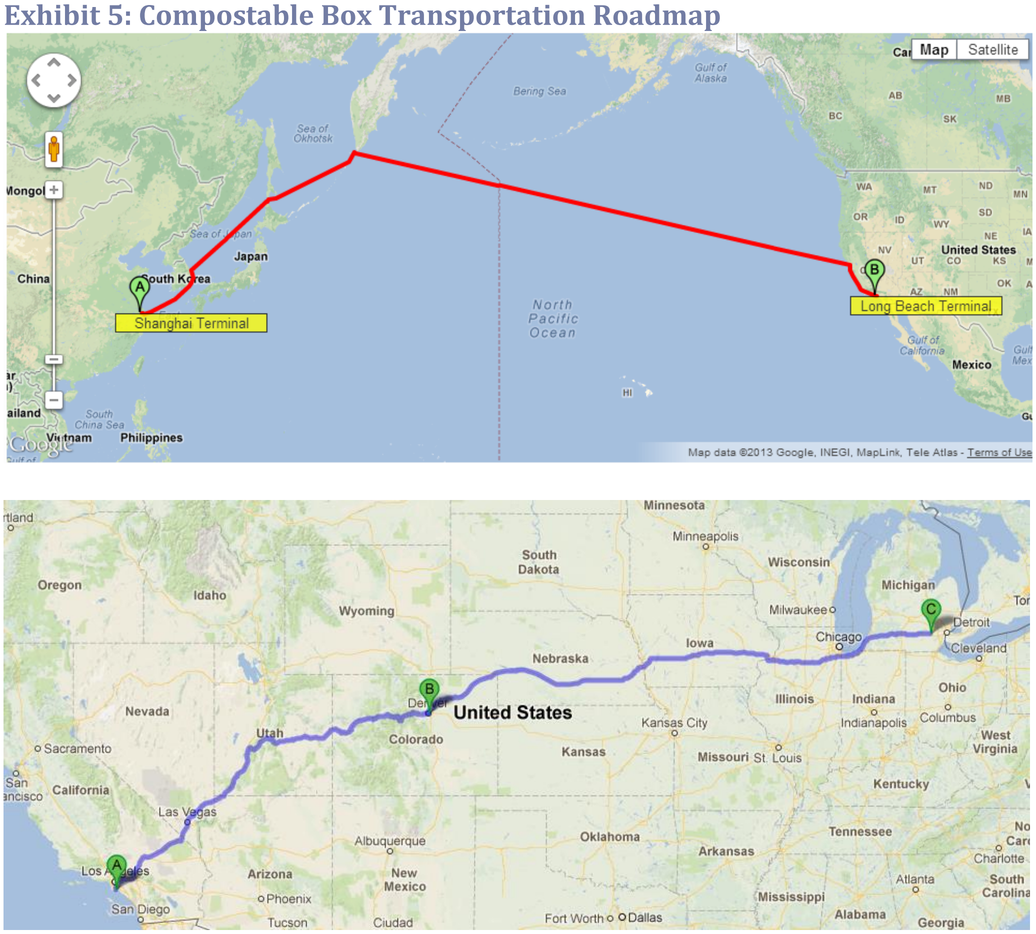


Exhibit 6: Cost Analysis

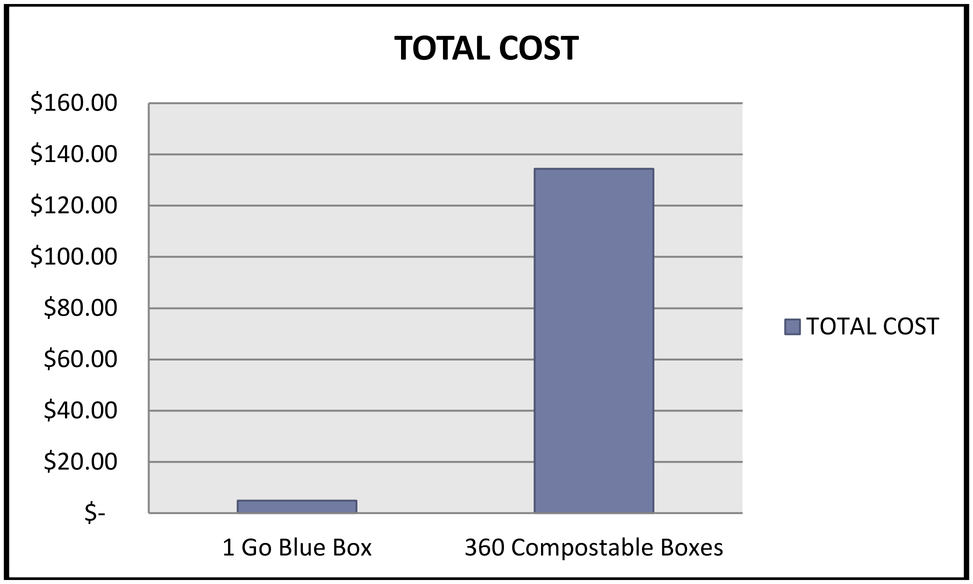
	Go Blue Box	Compostable Box
Price (per box)	$ 4.00	$ 0.37
Number of boxes	1.01	360
Total Price	**$ 4.04**	**$ 133.20**

Use Phase		
Washer Price	$ 40,281.00	
Depreciation/yr	$ 1,611.24	
Wash cycle time (minutes)	1	
Number of cycles	360	
Number of dishes/minute	101	
Go Blue Box Washes Total	14.2574	
Cost of Water	**$ 0.36**	
Cost of Electricity	**$ 0.52**	
Allocation of Depreciation	neligible	

End of Life Phase		
Weights of the Boxes (lbs)	0.09696	39.6
Weights of the Boxes (tons)	4.39803E-05	0.017962258
Percent Recycling	95%	0%
Percent Landfill	5%	90%
Percent Composting	0%	10%
Total volume recycled	4.17813E-05	0
Total volume landfilled	2.19902E-06	0.016166032
Total volume composted	0	0.001796226
Total EOL costs	**$ 0.00524**	**$ 1.18251**

TOTAL COST	**$ 4.93**	**$ 134.38**

Assumptions:
Assume 4 of the 101 dish slots in the washer are taken up by 1 Go Blue Box/cycle
No labor costs



Below is a comparison if there was less than ideal return rate of the Go Blue Boxes and 10 boxes were needed to meet the 360 uses.

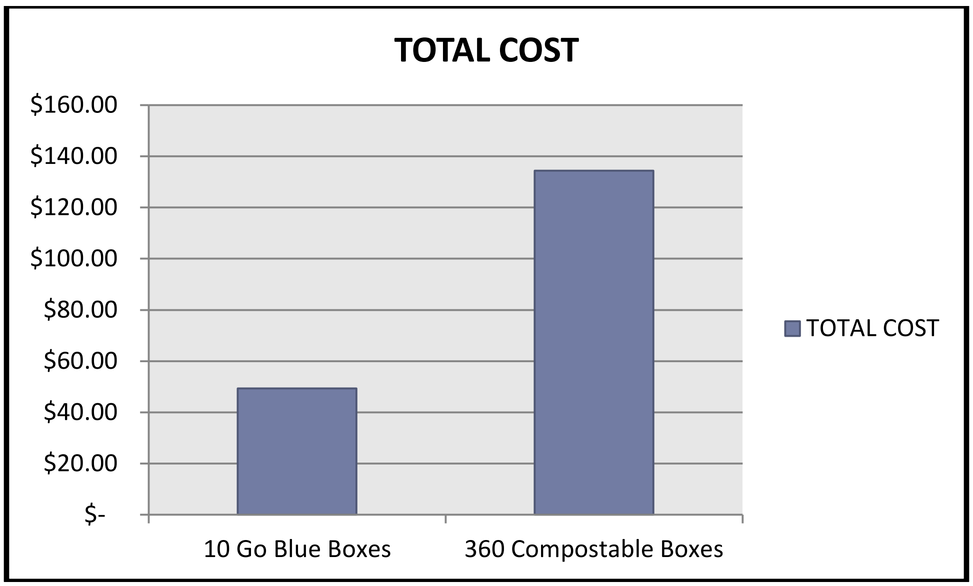


Exhibit 7: Underlying data breakdown for Use Phase

Water Usage for Hobart CCS86A	
Final Rinse at highest PSI Flow Pressure of 20 (gal/min)	2.21
Steam Consumption (gal/min) for 30% of minute wash cycle	0.089185258
Total Gallons	2.299185258
Water cost per gallon	$ 0.011
Water cost for 1 min wash	**$ 0.025**
Electricity Usage for Hobart CCS86A	
Gas Burner Electricty use/hr (kWh)	27.549
Electricty use/min (kWh)	0.45915
Electricity cost ($/kWh)	$0.08
Electricity cost for 1 min wash	**$0.04**

Assumption:
8.098 lb of steam/gal of water

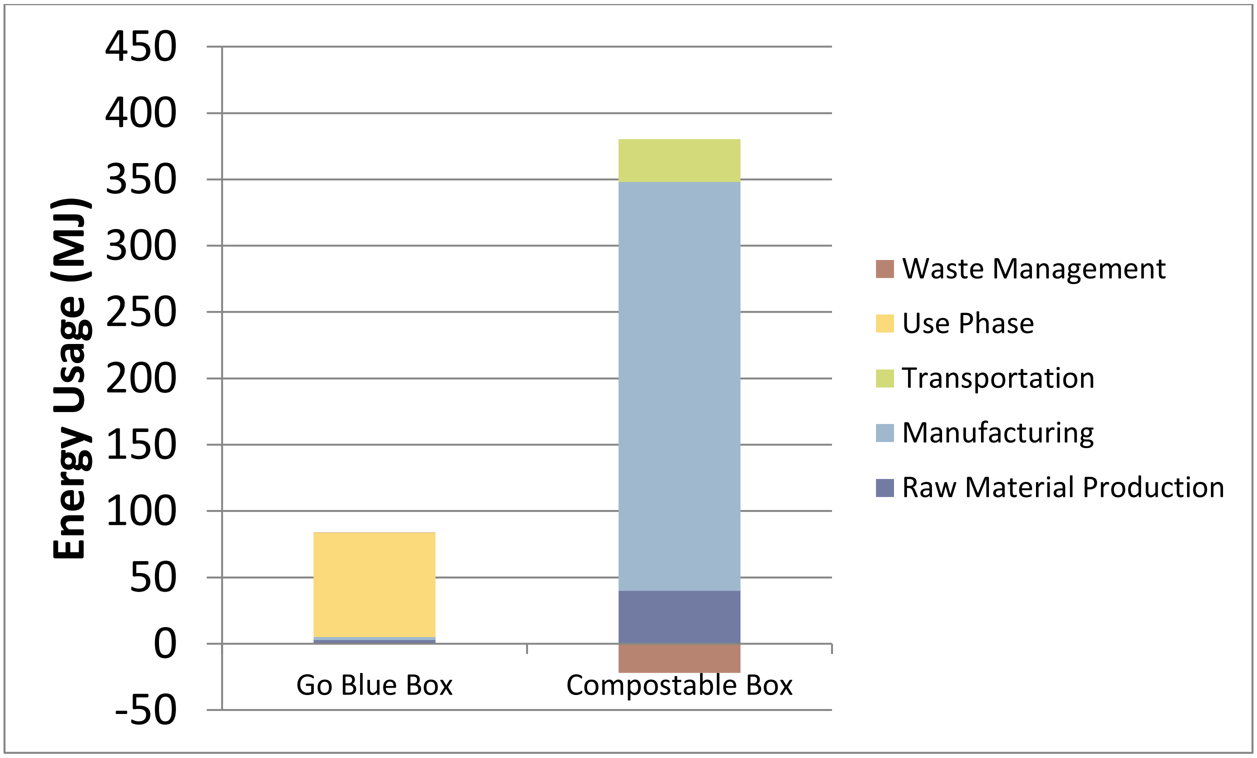
Exhibit 8: Energy Consumption, Water Consumption and GHG Emissions for 1 Go Blue Box

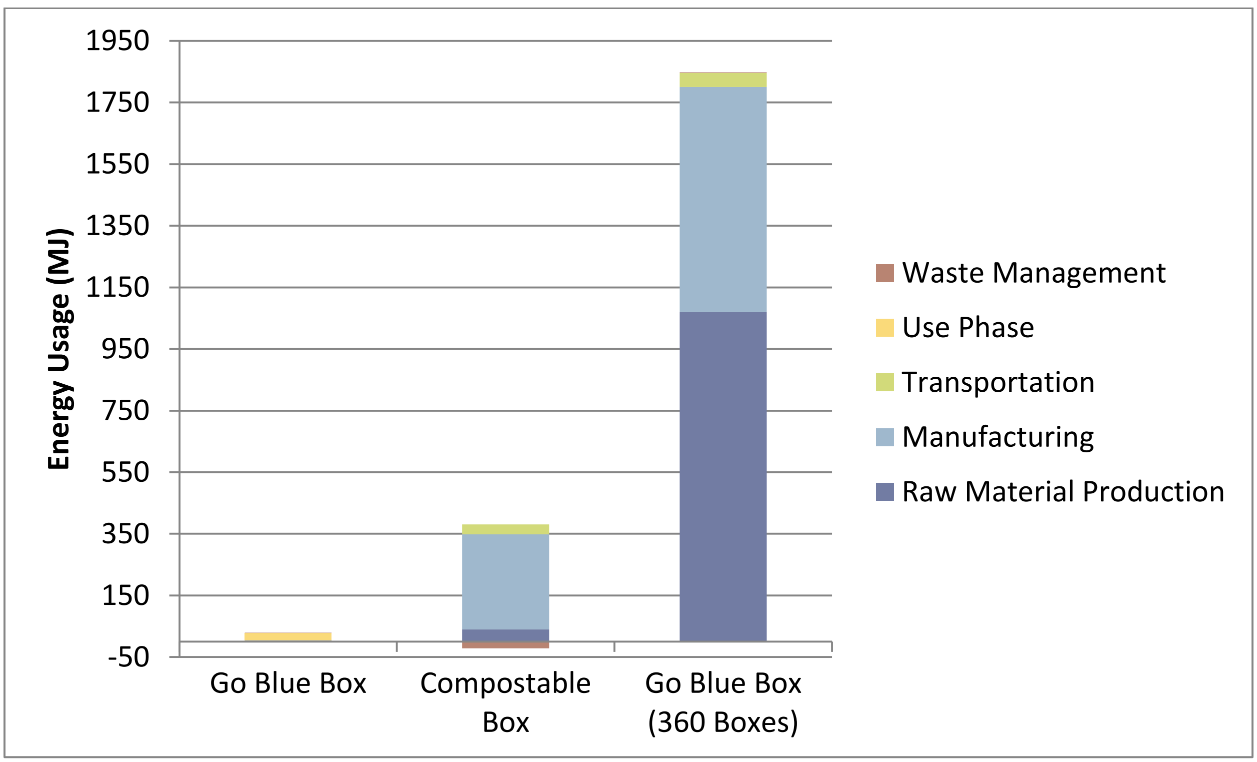
Go Blue Box	Energy Consumption (MJ)	Water Consumption (m^3)	Greenhouse Gas Emissions (kg CO_2)
Raw Material Production	2.970	0.000154	0.05568
Manufacturing	2.030	0.002226	0.12432
Transportation	0.138	~0	0.00869
Use	78.553	0.12	1.328861
Waste Management	0.006	~0	0.001058

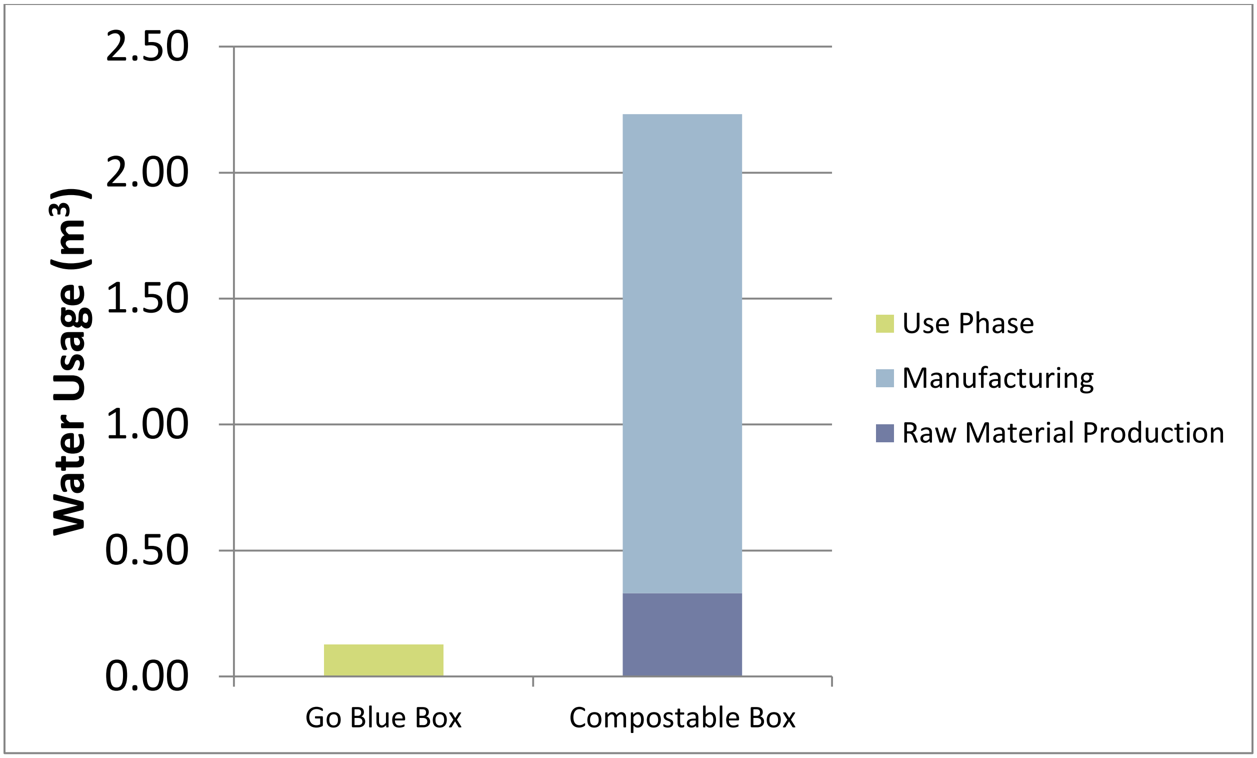
Exhibit 9: Energy Consumption, Water Consumption and GHG Emissions for 360 compostable boxes

Compostable Box	Energy Consumption (MJ)	Water Consumption (m^3)	Greenhouse Gas Emissions (kg CO_2)
Raw Material Production	40.1	0.33	0.1636
Manufacturing	308.053	1.90	14.44
Transportation	32.2	~0	2.22
Use	0	0	0
Waste Management	-21.875	~0	5.651

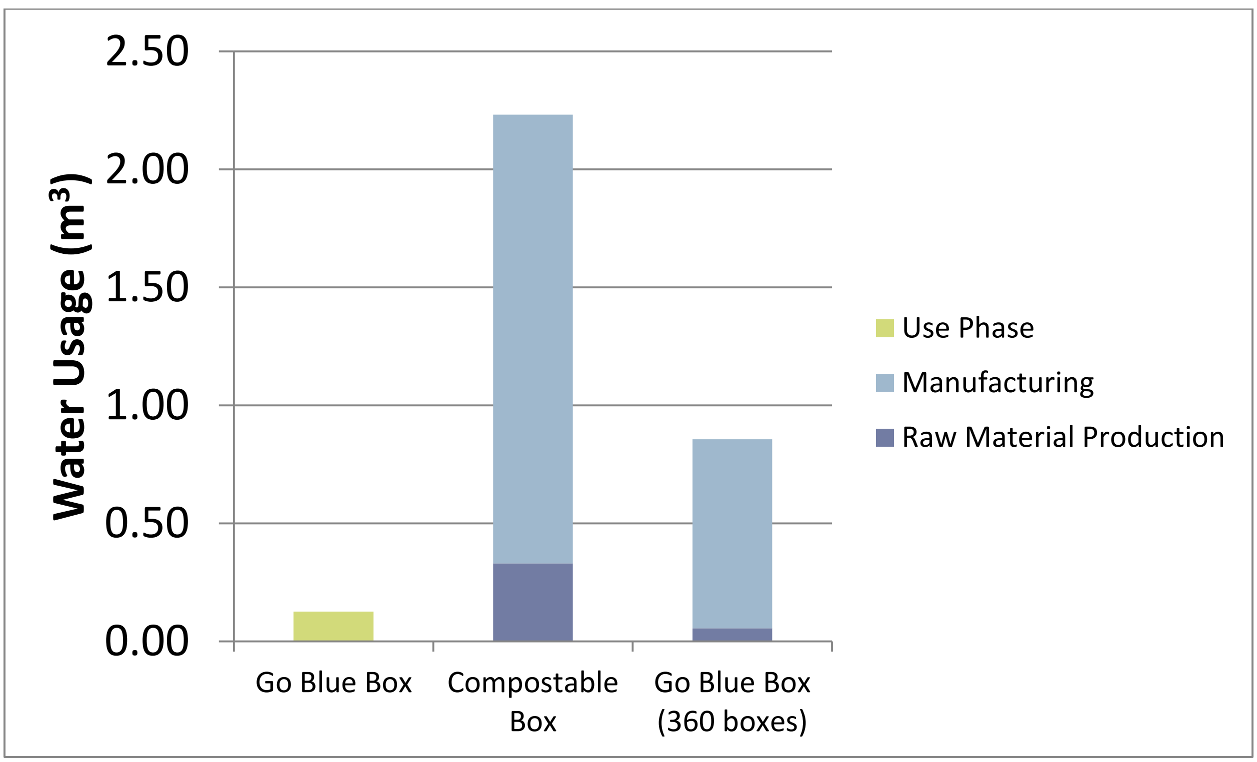
Exhibit 10: Energy Consumption, Water Consumption and GHG Emissions Comparisons



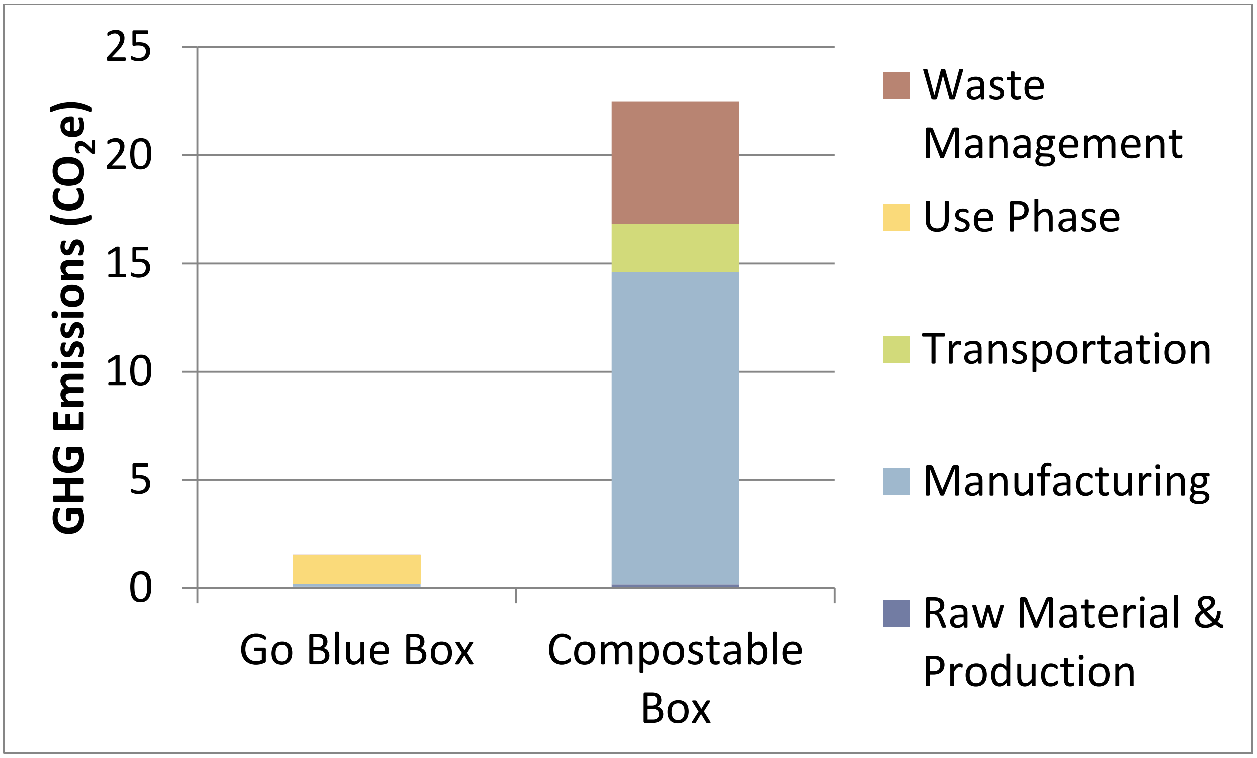




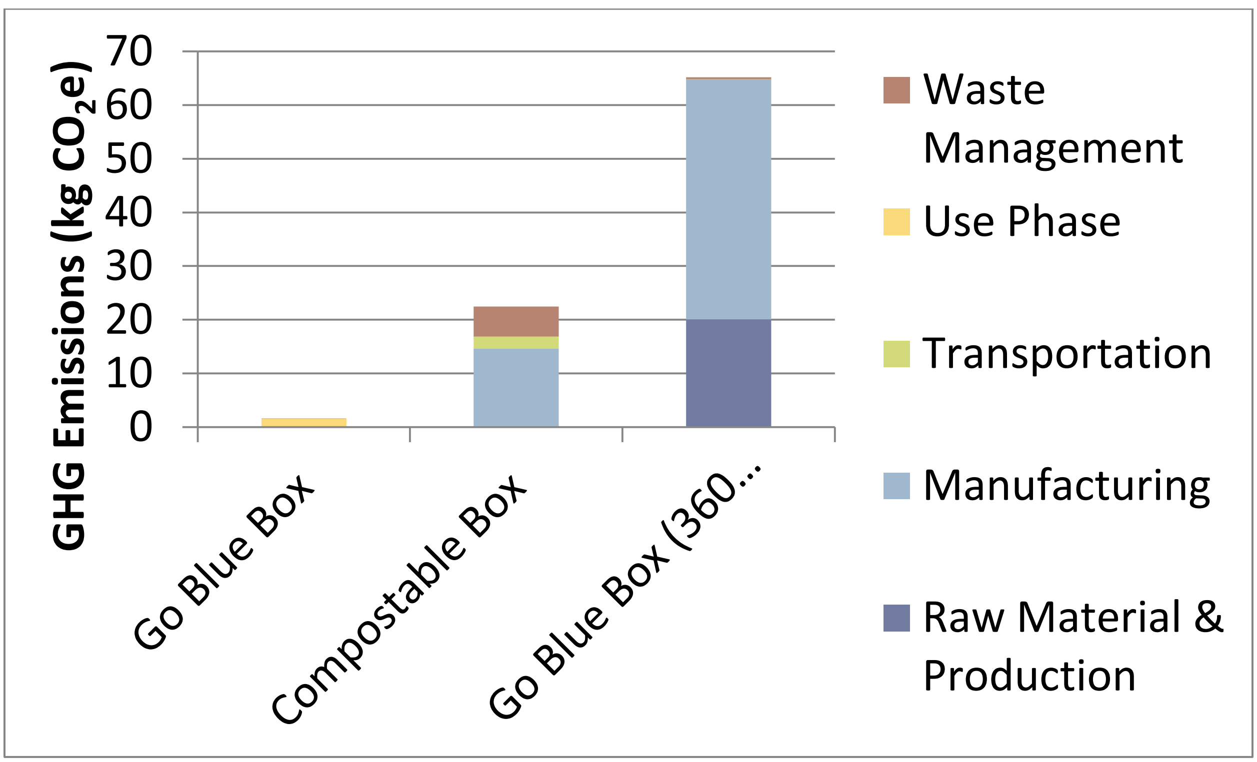
Water Usage (m³)
2.50
2.00
1.50
1.00
0.50
0.00
Go Blue Box
Compostable Box
Use Phase
Manufacturing
Raw Material Production



Water Usage (m³)
2.50
2.00
1.50
1.00
0.50
0.00
Go Blue Box
Compostable Box
Go Blue Box (360 boxes)
Use Phase
Manufacturing
Raw Material Production



GHG Emissions (CO_2e)
25
20
15
10
5
0
Go Blue Box
Compostable Box
Waste Management
Use Phase
Transportation
Manufacturing
Raw Material & Production



GHG Emissions (kg CO_2e)
70
60
50
40
30
20
10
0
Go Blue Box
Compostable Box
Go Blue Box (360…
Waste Management
Use Phase
Transportation
Manufacturing
Raw Material & Production

Bibliography

1. Sugarcane Clamshells. Retrieved March 20, 2013. Retrieved from http://www.ecoproducts.com/sugarcane_clamshells.html.
2. The Life Cycle of the Eco-Takeout [Brochure]. Retrieved from www.ecotakeouts.com.
3. Go Green with G.E.T.'s Eco-Friendly Products [Brochure]. Retrieved from www.ecotakeouts.com.
4. R Grousset (Personal Communication, March 10, 2013).
5. C. Vanwagnen (Personal Communication, March 23, 2013).
6. *Transit Time*. Retrieved from http://www.searates.com/reference/portdistance/
7. EcoIndicator 95 v2.06 e. SimaPro
8. Hobart CCS86A Specifications. Retrieved from https://my.hobartcorp.com/resourcecenter/ProductDocumentation/F-8111.pdf
9. "Bagasse Life Cycle," Greenway. Retrieved from http://www.greenwaylink.com/product-life-cycle/bagasse-product-life-cycle/
10. Sugar cane production data, Food and Agriculture Organization of the United Nations. Retrieved from http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor.
11. China sugarcane production, 40% Guangxi. Retrieved from http://www.fao.org/docrep/005/X0513E/x0513e18.htm
12. Poopak, Sotoodehnia Poopak and P. Agamuthu. "Life cycle impact assessment (LCIA) of paper making process in Iran." *African Journal of Biotechnology* .Vol. 10(24), pp. 4860-4870. June 6, 2011 Retrieved from http://www.academicjournals.org/ajb/PDF/pdf2011/6Jun/Poopak%20and%20Agamuthu.pdf
13. *Polypropylene*. (2005). Retrieved from Polymer Science Learning Center : http://www.pslc.ws/macrog/pp.htm
14. *Injection Molding*. (n.d.). Retrieved from University of Moratuwa EN 495 Independent Study: http://www.ent.mrt.ac.lk/~040087/
15. *Polypropylene (PP)*. (n.d.). Retrieved from UL IDES: http://www.ides.com/pm/2_polypropylene.asp

End Notes

[i] http://www.ecoproducts.com/sugarcane_clamshells.html
[ii] http://www.epa.gov/ttnchie1/ap42/ch01/final/c01s08.pdf
[iii] http://www.greenwaylink.com/product-life-cycle/bagasse-product-life-cycle/