TECHNICAL APPENDIX:

Methodology and Documentation for GHG Emissions Reduction Estimate

Overview

The estimated GHG emissions reduced by the reusable foodware program are calculated using the following high-level approach:

1. Estimate types and masses of materials source reduced as a result of reusable foodware program
2. Calculate source reduction GHG emissions impacts using the Excel version of EPA's Waste Reduction Model (WARM) Version 16
3. Estimate GHG emissions impacts of proposed reusable foodware program during the project time period
4. Subtract estimated GHG emissions from reusable foodware program (Step 3) from estimate source reduction benefits (Step 2)

Step 1: Estimating annual single-use product units and mass of material

Perpetual created a publicly available Foodservice Disposables Quantification Tool (see attachment) that uses national estimates of single-use foodware sold to restaurants to estimate the number of units and mass of disposable items by material type as a function of community population represented as the percent of the total U.S. population. Using this tool, we first estimated the quantity of disposable foodware currently used by restaurants in the coalition communities.

Table 1. Inputs for Foodservice Disposables Quantification Tool

Total Population of Coalition Communities (2021)	158,690
Total U.S. Population (2021)	331,900,000
Coalition Population as % of U.S. Population	0.05%

The focus of the reusable foodware program is to replace hot and cold cups and food containers used for takeout and delivery. We therefore set the tool to limit the results to products used for "off-premises" consumption and only use the estimates for hot cups, cold cups, and containers. Pizza boxes are included in the tool's "container" category, but we exclude them as there are not yet examples of successful reusable pizza box programs. We also do not include: lids and domes, bags, dinnerware (e.g., plates and bowls), utensils (e.g., cutlery, straws), napkins, wraps, and other (e.g., trays, cup sleeves, and portion cups). We anticipate the reusable foodware program may reduce some of these products, especially cup and container lids and cup sleeves, but there is not currently data available to make estimates with any reasonable confidence. Further, some reusable programs opt to continue using single-use lids on reusable cups. Overall, we expect these choices to result in an underestimate of the reductions in waste and lifecycle GHG emissions.

The initial results for the coalition communities appear in Table 2.

Table 2. Initial Results from Foodservice Disposables Quantification Tool

Product	Units (millions)	Total Mass (short tons)	Total Paper (short tons)	Total Plastic incl. PLA (short tons)	Total Aluminum (short tons)
Containers	8.8	204.2	70.2	133.3	0.7
Cups	30.7	421.2	190.4	230.7	0.0
Total	39.4	625.4	260.7	364.0	0.7

The tool's results are based on industry data from 2016. Therefore, we estimate current values using an estimated total (not annual) growth rate of 12.6% based on fast food restaurant industry data.[1] The adjusted results appear in Table 3.

Table 3. Results from Foodservice Disposables Quantification Tool Adjusted for Industry Growth

Product	Units (millions)	Total Mass (short tons)	Total Paper (short tons)	Total Plastic (short tons)	Total Aluminum (short tons)
Containers	9.9	229.9	79.1	150.1	0.8
Cups	34.5	474.3	214.4	259.8	0.0
Total	44.4	704.2	293.5	409.9	0.8

These results provide a valuable baseline estimate for the annual material flowing through the coalition communities in the form of single-use containers and cups served by restaurants for off-premise dining (e.g., takeout and delivery). Note that these figures do not include estimates for the quantity of single-use products used in K-12 schools. We will add those estimates later in the process.

These results also enable us to estimate the average mass of each material type per single-use cup and container. To do that, we divide the total mass of each material type from Table 3 by total units of product. The results are shown in Table 4. If we multiply the numbers in Table 4 by total cups and containers eliminated because of the reusable foodware program, the result is source reduction by material type.

Table 4: Total Mass Divided by Total Units

Product	Units	Average Total Mass (short tons)	Average Paper (short tons)	Average Plastic (short tons)	Average Aluminum (short tons)
Containers	1	0.00002331164384	0.00000801598173	0.00001521917808	0.00000007648401

[1] IBIS World. "Fast Food Restaurants in the US – Market Size 2002-2027." Accessed on September 6, 2021

Cups	1	0.00001373613829	0.00000621135029	0.000007524787997	0

The next necessary pieces of information are the quantities of single-use cups and containers replaced by a reusable foodware program during a given period of time. For illustrative purposes, we will begin with the total estimated cup and container used in the coalition communities from 2025 to 2030. The results for 2025 through 2050 appear in Table 12.

The reusable foodware program will not be operational during the project planning, design and set up phases and, therefore, will not replace any single-use products in 2025. The system launches in 2026 with 60 restaurants (approximately 10% of restaurants in coalition communities) and the number of participating restaurants growing at a conservative rate of ~10% per year, which in this case equates to 6 or 7 additional participating restaurants each year. There is uncertainty in the estimated number of restaurants participating at launch and the number that can be recruited each year. These are numbers Perpetual is comfortable with, however, based on its experience with restaurant engagement and the effectiveness of the budgeted $1,000 available in transition support for each restaurant agreeing to participate.

Based on the adjusted annual quantity of cups and containers from the Foodservice Disposables Quantification Tool (Table 3) and the total number of restaurants in the coalition communities (560), the average restaurant in the coalition communities generates 43 single-use containers per day and 150 single-use cups per day for off-premises dining.

Based on the enthusiastic support from the Hoboken Board of Education, we anticipate a minimum of 3 of their 5 public schools to participate in the reusable foodware program. In 2023 the student enrollment in the five schools was 3,170 or an average of 634 students per school. Assuming an average 60% of students eat a school lunch daily, 30% of students eat a school breakfast daily,[2] one tray per meal, and 180 school days per year, the result is 376,596 single use trays per year. For our calculations here we assume the molded fiber and foam trays are similar in mass to the molded fiber and plastic containers used by restaurants and therefore use the same mass conversion factors from Table 4. There is not yet enough information to make the assumption that we will replace single-use cups in these schools.

In the absence of data, a commonly used conservative assumption is that the number of reusable product "uses" is equivalent to the number of single-use cups and containers they are replacing. For example, the assumption is that an average of only one single-use cup is used per beverage served, which discounts the possibility of "double-cupping" hot beverages, and that the consumer does not displace additional single-use items by refilling the reusable cup before it is collected and washed.

Table 5: Forecasted Annual Reusable Product Uses in Coalition Communities (including Schools)

Year	# Participating Restaurants at End of Year	# Participating Schools	Restaurant Cup Uses	Restaurant Container Uses	School Container Uses	Total Container Uses

[2] School meal participation based on the Food Research and Action Center report, "The Reach of School Breakfast and Lunch" (https://frac.org/wp-content/uploads/school-meals-2023.pdf). During the 2021-2022 school year, average daily participation in New Jersey was 813,439 students for lunch and 394,451 for breakfast, out of a total of ~1.32 million public school students in the state (https://ballotpedia.org/Public_education_in_New_Jersey)

2025	0	0	0	0	0	0
2026	66	3	3,993,190	1,140,503	308,124	1,448,627
2027	73	3	4,408,008	1,258,990	308,124	1,567,114
2028	80	3	4,822,826	1,377,477	308,124	1,685,601
2029	87	3	5,237,645	1,495,963	308,124	1,804,087
2030	94	3	5,652,463	1,614,450	308,124	1,922,574
Total			24,114,132	6,887,383	1,540,620	8,428,003

To arrive at estimated source reduction by material category we then multiply the uses of each product type by the appropriate conversion factor and then sum the results for each material. The results appear in Table 6.

Table 6: Forecasted Source Reduction by Material Category (2025 through 2030)

	Total Paper	Total Plastic	Total Aluminum	Total Material
Year	(short tons)	(short tons)	(short tons)	(short tons)
2025	0	0	0	0.0
2026	36.4	52.1	0.1	88.6
2027	39.9	57.0	0.1	97.1
2028	43.5	61.9	0.1	105.5
2029	47.0	66.9	0.1	114.0
2030	50.5	71.8	0.1	122.5
Total	217.3	309.7	0.6	527.7

Step 2: Calculating source reduction GHG emissions impacts using EPA's WARM Version 16

For the WARM model, we make the following assumptions:

- "Mixed paper (general)" is used as a proxy for the variety of papers used in single-use foodware products.
- The plastics most commonly used in single-use foodware are PET, PP, PS, and PLA. In the absence of data on the proportion of those materials in U.S. single-use foodware, we split total plastic mass evenly between them. In other words, we assume the total plastic calculated in Step 1 is composed of 25% PET, 25% PP, 25% PS, and 25% PLA.
- "Aluminum cans" is used as a proxy for aluminum foodware containers.
- Single-use foodware products are typically contaminated with food residue and negligible quantities are collected for recycling or composting.
- WARM inputs 3 to 10 were left at "default" or "national average."

Table 7: Materials Management Assumptions

Material	Baseline Management		Alternative Management
	Landfilled	Recycled	Source Reduction
Mixed Paper	100%	0%	100%
PET	100%	0%	100%
PP	100%	0%	100%
PS	100%	0%	100%
PLA	100%	0%	100%
Aluminum	100%	0%	100%

Table 8: EPA WARM Version 16 Outputs (Mt CO2e)

	2025	**2026**	**2027**	**2028**	**2029**	**2030**	**Total**
Mixed Paper	0	-223.8	-245.32	-267.46	-288.98	-310.5	-1336.06
PET	0	-28.51	-31.36	-33.99	-36.63	-39.26	-169.75
PP	0	-20.09	-22.09	-23.95	-25.8	-27.66	-119.59
PS	0	-32.76	-36.03	-39.06	-42.08	-45.11	-195.04
PLA	0	-10.53	-11.59	-12.56	-13.53	-14.5	-62.71
Aluminum	0	-0.48	-0.48	-0.48	-0.48	-0.48	-2.4
Total	0	-316.17	-346.87	-377.5	-407.5	-437.51	-1885.55

Step 3: Estimate GHG emissions impacts of proposed reusable foodware program

There are not yet any standardized methods for estimating the impacts of reusable foodware programs, and individual lifecycle assessments use a wide variety of assumptions for key variables. For their report, Reuse Wins,[3] the non-profit organization Upstream analyzed numerous lifecycle assessments and found that:

- A stainless steel reusable item performs 5 times better than single-use PET products on GHG emissions
- A stainless steel reusable item performs 10 times better than single-use lined paper products on GHG emissions

These estimates come from the chart on page 89 of their report ("CO2 Emissions per Cup When Landfilled"). For example, a single-use PET cup results in 0.047 kg CO2e of lifecycle GHG emissions when

[3] Miriam Gordon, *Reuse Wins: The environmental, economic, and business case for transitioning from single-use to reuse in food service* (Upstream, 2021), 89

landfilled (nearly all cups are landfilled) and a stainless steel cup generates only 0.01 kg CO2e per use assuming 500 lifetime uses, which is approximately 5 times better.

Until better models become publicly available and/or we know the specific design of the implemented reusable foodware program, we estimate the carbon footprint of the program assuming it will be roughly 5 times better than plastic, 10 times better than paper, and 5 times better than aluminum. A simple estimate for reusable program GHG emissions is therefore achieved by dividing the source reduction outputs from WARM by the number of times better the reuse program is for each type of single-use material.

In Table 9 we demonstrate this method using the total of WARM outputs from 2025 through 2030 in Table 8. In Table 10 are the results for each year from 2025 through 2030.

Table 9: Method for Estimating GHG Emissions from Reusable Foodware Program (2025-2030 Total)

	(A) WARM Outputs (Mt CO2e)	**(B)** Reuse Factor	**(A / B)** Reusable Foodware Program Emissions (Mt CO2e)
Paper	1,336.06	10	133.606
Plastic (incl. PLA)	547.09	5	109.418
Aluminum	2.4	5	0.48
TOTAL	*1,885.55*		*243.50*

Table 10: Reusable Foodware Program GHG Emissions Estimates by Year (2025 to 2030)

Material Source Reduced	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Total**
Paper	0	22.38	24.532	26.746	28.898	31.05	133.606
Plastic	0	18.378	20.214	21.912	23.608	25.306	109.418
Aluminum	0	0.096	0.096	0.096	0.096	0.096	0.48
Total	0	40.854	44.842	48.754	52.602	56.452	243.504

Step 4: Subtract estimated GHG emissions from reusable foodware program from estimated source reduction benefits

The final step is to simply subtract the GHG emission footprint of the reusable foodware program from the estimated source reduction benefits from WARM. The result is our net GHG emission reductions due to replacing single-use cups and containers with a reusable foodware program in the coalition community. Table 11 demonstrates this method using the total emissions for 2025 through 2030. Column A uses the total WARM outputs from Table 8. Column B uses the total reusable foodware GHG emission from Table 9.

Table 11: Method for Calculating Net GHG Emissions Benefits from Reusable Foodware Program

	(A)	**(B)**	**(A-B)**

	WARM Outputs (Mt CO2e)	Reusable Foodware Program Emissions (Mt CO2e)	Net GHG Reduction
Paper	1,336.06	133.606	1,202.45
Plastic	547.09	109.418	437.672
Aluminum	2.4	0.48	1.92
TOTAL	*1,885.55*	*243.50*	*1,642.05*

Table 12 shows the results of applying this method for each individual year, which also give us the cumulative estimated GHG emissions reductions for 2025 through 2030.

Table 12: Annual Net Mt CO2e Reductions (2025-2030)

	2025	**2026**	**2027**	**2028**	**2029**	**2030**	**Total**
EPA Warm Output	0	316.17	346.87	377.5	407.5	437.51	1885.55
Estimated Reuse Program Emissions	0	40.854	44.842	48.754	52.602	56.452	243.504
Net GHG Reduction for Measure	0	275.316	302.028	328.746	354.898	381.058	1642.046

Tabel 12 shows the GHG emissions results for 2025 through 2050 when applying the aforementioned methods and assuming the growth rate in participating restaurants remains constant.

Table 12: Annual Net Mt CO2e Reductions (2025-2050)

Year	Source Reduction	Reuse Program Impact	Net Reduction	Cumulative
2025	0	0	0	0
2026	316.17	40.854	275.32	275.32
2027	346.87	44.842	302.03	577.34
2028	377.5	48.754	328.75	906.09
2029	407.5	52.602	354.90	1,260.99
2030	437.51	56.452	381.06	1,642.05
2031	468.7	61	408.16	2,050.21
2032	499.31	64	434.86	2,485.07
2033	529.3	68.293	461.01	2,946.08
2034	560.02	72.285	487.74	3,433.81
2035	590.64	76.196	514.44	3,948.26
2036	620.63	80.042	540.59	4,488.85

2037	651.34	84.032	567.31	5,056.15
2038	681.34	87.88	593.46	5,649.61
2039	711.97	91.792	620.18	6,269.79
2040	742.67	95.78	646.89	6,916.68
2041	772.66	99.627	673.03	7,589.71
2042	803.16	103.575	699.59	8,289.30
2043	834.49	107.627	726.86	9,016.16
2044	864.49	111.475	753.02	9,769.18
2045	894.48	115.321	779.16	10,548.34
2046	924.49	119.171	805.32	11,353.66
2047	955.8	123.22	832.58	12,186.24
2048	985.82	127.072	858.75	13,044.98
2049	1015.81	130.918	884.89	13,929.88
2050	1046.53	134.91	911.62	14,841.50
Total	**17039.2**	**2197.705**	**14,841.50**	

Discussion of Assumptions and Uncertainties

As there are few, if any, examples of community-scale reusable foodware programs, there is still a lot of uncertainty in every variable, from likelihood of consumer and business adoption to expected environmental outcomes. Forecasts of consumer and business adoption, unfortunately, will remain highly uncertain until community-scale, immersive reusable foodware programs, like the one proposed in this application, are implemented such that consumers and businesses have the opportunity to participate with a level of convenience at or near that of the highly-optimized single-use packaging paradigm.

Data from pilot-scale operations and an increasing amount of academic and consulting research have, however, begun to converge on the variables with the most influence on estimated environmental outcomes. The following list, which is not by any means comprehensive, is compiled from several sources, especially those footnoted here.[4,5]

Product Considerations:

- **Single-use Products:** Because of limited data, there is medium to high uncertainty regarding the GHG emissions associated with the single-use product reference case against which reusable

[4] Christian Hitt, Jacob Douglas, Gregory Keoleian, *Parametric life cycle assessment modeling of reusable and single-use restaurant food container systems*, Resources, Conservation and Recycling, Volume 190, 2023, 106862, ISSN 0921-3449, https://doi.org/10.1016/j.resconrec.2022.106862.

[5] *Assessing Climate Impact: Reusable Systems vs. Single-use Takeaway Packaging*, Prepared for TOMRA, Zero Waste Europe, and Reloop by Eunomia Research & Consulting, September 2023.

foodware programs are compared. Lifecycle analyses typically choose only a few products for comparison, but the extent to which these products are used by the restaurant industry is difficult to estimate. For example, there is not a publicly available precise estimate of the total number of annual takeout containers served each year in the U.S., the number made from each different material type, the average mass, and so on. The Foodware Disposables Quantification Tool was an effort to address this information gap, but it also makes numerous assumptions in the absence of actual industry data and is already out of date as it is based on industry data from 2016. Given the changes in the foodservice industry during and after the COVID-19 pandemic, it is possible that there is a large margin of error in a lot of key assumptions. Overall, if paper products comprise a much larger share of the single-use product market than we estimated, then our calculated GHG benefits would change significantly. We are also unable to account for the future mix of single-use products and their associated carbon footprints in our 2025 to 2050 forecasts.

- **Reusable Products:** Assumptions made about the reusable products selected for a reusable program have a significant impact on GHG footprint. The most common products used for reusable foodware programs are made from either polypropylene or stainless steel. The former has a much smaller manufacturing footprint than the latter.
- **Throughput of Professional Washing Process:** The total number of products that can be throughput in a single wash has a notable impact on GHG emissions. For example, cups have a much smaller GHG footprint from washing than do takeout containers because many more cups can fit on a rack or conveyor belt. GHG emissions from a reuse program are therefore sensitive to metrics such as average reusable product size, products per rack, and reusable products washed per hour.

Consumer Behavior Considerations:

- **Return Rate**: Depending on the type of product being replaced (e.g,. mass and material type), return rates must be in the 83% to 97% range in order for a reuse program to achieve net GHG reductions. Based on conversations with service providers, 90% return rate is generally feasible and is what is used as the starting return rate in the financial assumptions for this application regarding purchase of replacement products. Some programs have reported return rates above 97% so we do believe this is realistic for a well-designed system.
- **Dedicated Return Journeys:** Generally speaking, reusable foodware programs will have difficulty achieving net environmental benefits if consumers use combustion-engine vehicles to make trips dedicated to returning reusable products. We assume this will not happen and the system will be designed specifically to keep these dedicated trips to the bare minimum.

Use Phase Considerations:

- **Energy:** Assumptions made about the types and quantities of energy, fuel, and hot water used for washing, collection, and distribution of reusable products are key because these processes are repeated over and over again for reusable products. For example, using electric trikes for collection and delivery instead of diesel box trucks and powering a washing facility with renewable energy would increase the net GHG benefits compared to the estimates we provided. This is part of the reason for using a parametric modeling approach during the system design phase to ensure best-case scenario environmental outcomes.