Supplemental Information for Cataract Surgery & Environmental Sustainability: Waste & Life Cycle Assessment of Phacoemulsification at Aravind Eye Care System

A. Life Cycle Inventory Data

Table 1: Life Cycle Inventory for Single Average Phacoemulsification at Aravind Eye Hospital.
**all unit processes come from the LCI database Ecoinvent, 3 – allocation, default – unit EXCEPT the pharmaceutical category which was calculated using Economic Input Output LCA (EIOLCA) and the North American Industry Classification System (NAICS) sector number 325412: Pharmaceutical Preparation Manufacturing; HDPE= high density polyethylene; GLO= global; OR= operating room; Alloc Def, U= Allocation default, unit (reference to the Ecoinvent database); RoW= rest of world; IN= India; kg= kilograms; m3= cubic meters; kWh= kilowatt hours; MJ= megajoules*

Category	Material	Example Products	Unit Process*	Allocated Quantities per Case	Unit
Single-Use Disposable Items	Steel	blades, needles	Steel, chromium steel 18/8 {GLO}| market for | Alloc Def, U	0.015	kg
	Cotton	gauze	Textile, woven cotton {GLO}| market for | Alloc Def, U	0.016	kg
	Polypropylene	patient face drape, syringes	Polypropylene, granulate {GLO}| market for | Alloc Def, U	0.113	kg
	Polycarbonate	eye shield	Polycarbonate {GLO}| market for | Alloc Def, U	0.003	kg
	HDPE	packaging	Polyethylene, high density, granulate {GLO}| market for | Alloc Def, U	0.0002	kg
	Glass, white	packaging	Packaging glass, white {GLO}| market for | Alloc Def, U	0.013	kg
	Paper	packaging and directions	Kraft paper, bleached {GLO}| market for | Alloc Def, U	0.067	kg
	Polybutadiene	gloves	Polybutadiene {GLO}| market for | Alloc Def, U	0.012	kg
Reusable Items and Processes	Steel - Instruments	surgical instruments and tools	Steel, chromium steel 18/8 {GLO}| market for | Alloc Def, U	0.00015	kg
	Steel - Bins	instrument trays	Steel, chromium steel 18/8 {GLO}| market for | Alloc Def, U	0.00061	kg
	Polyurethane	staff surgical footwear	Polyurethane, flexible foam {GLO}| market for | Alloc Def, U	0.00072	kg

	Cotton	gowns, blankets, masks, bouffant	Textile, woven cotton {GLO}| market for | Alloc Def, U	0.00132	kg
	PROCESS - Linens	laundry in Central Sterile	Combination: 27.4g/kg cotton of Layered sodium silicate, SKS-6, powder {GLO}| market for | Alloc Def, U and 1.5kWh/kg cotton for electricity in laundering machines	0.00132	kg
	PROCESS - Autoclave	instrument sterilization in Central Sterile	Combination: 0.5kWh/tray electricity between cases & 2.2kWh/tray for end-of-day cleaning and sterilization	1	tray
End-of-Life and Disposal	Incineration	Biohazardous Waste - sharps, gloves, gauze	Hazardous waste, for incineration {GLO}| market for | Alloc Def, U	0.016	kg
	Inert Waste - Landfill	Municipal Solid Waste - all other items discarded in OR	Inert waste, for final disposal {GLO}| market for | Alloc Def, U	0.044	kg
	Recycling - Metal	Recycling - aluminum tabs, other metal items	Steel and iron (waste treatment) {GLO}| recycling of steel and iron | Alloc Def, U	0.018	kg
	Recycling - White Glass	Recycling - bottles	Packaging glass, white (waste treatment) {GLO}| recycling of packaging glass, white | Alloc Def, U	0.023	kg
	Recycling - Mixed Plastics	Recycling - patient face drapes, packaging	Mixed plastics (waste treatment) {GLO}| recycling of mixed plastics | Alloc Def, U	0.075	kg
	Recycling - Paper	Recycling - packaging and directions	Paper (waste treatment) {GLO}| recycling of paper | Alloc Def, U	0.062	kg
Pharma and Chemicals	Formaldehyde	OR fumigation	Formaldehyde {GLO}| market for | Alloc Def, U	0.0012	kg
	Pharmaceuticals*	eye drops & injections: dilation, block, salt solutions, antibiotics	EIOLCA - NAICS sector 325412: Pharmaceutical Preparation Manufacturing	0.83	2002$US
Water	Water Treatment	water for hand washing, instrument cleaning	Tap water {RoW}| tap water production, underground water with disinfection | Alloc Def, U	300	kg

	Wastewater - GLO Average	wastewater treatment	Wastewater, average {RoW}| treatment of, capacity 1E9l/year | Alloc Def, U	0.3	m3
Energy	Electricity	Indian electric grid	Electricity, high voltage {IN}| market for | Alloc Def, U	0.70	kWh
	Diesel	combustion of diesel fuel	Diesel, burned in diesel-electric generating set {GLO}| market for | Alloc Def, U	1.04	MJ Diesel

Table 2: Pharmaceuticals Used in Phacoemulsification at Aravind Eye Hospital & Assumptions about Usage and Cost

Pharmaceutical	Bottle Size	Branded Drug Name	Stage Used	Purpose	# Uses before Disposal	Unit Cost (rps) 2014	Unit Cost (USD) 12/2014 exchange rate	Total Cost (USD) / case	Total Cost (rps) / case
Ketlur Ls Eye Drops 0.4%,			Ward, pre-op		25	₹ 52.00	$ 0.84	$ 0.03	₹ 2.08
Oflaxacin 0.3%	5mL	Auroflox	Ward, pre-op	antibiotic	25	₹ 40.00	$ 0.65	$ 0.03	₹ 1.60
Povidone Iodine Solution 5%	5mL	Aurdone	Pre-Block, Surgical Prep	anti-infective	25	₹ 25.00	$ 0.40	$ 0.02	₹ 1.00
Tropicamide 0.8% with Phenylephrine 5% Eye Drops	5mL	Auromide Plus	Pre-Block, Surgical Prep	Mydriatics and Cycloplegics	25	₹ 40.00	$ 0.65	$ 0.03	₹ 1.60
Homatropine 2%	5mL	Aurohom	Pre-Block, Surgical Prep	Mydriatics and Cycloplegics	25	₹ 29.00	$ 0.47	$ 0.02	₹ 1.16
Chlorhexidine gluconate 0.5% and 2-Propanol 70%	500mL	Aurorub	Block	hand cleaning	100	₹ 164.00	$ 2.65	$ 0.03	₹ 1.64
Hyaluronidase Injection	3mg	Facidase	Block		20	₹ 110.00	$ 1.77	$ 0.09	₹ 5.50
Lignocaine Hydrochloride 2% with Adrenaline Bitartrate	30mL	Xylocaine with Adrenaline	Block	Local Anesthetic	20	₹ 28.00	$ 0.45	$ 0.02	₹ 1.40
Lignocaine Hydrochloride Injection 2%	30mL	Xylocaine Plain	Block	Local Anesthetic	20	₹ 31.00	$ 0.50	$ 0.03	₹ 1.55
Antimicrobial Handwash Solution	500mL	Auroscrub	Surgical Prep	hand cleaning	200	₹ 164.00	$ 2.65	$ 0.01	₹ 0.82
Povidone Iodine Solution 10%	500mL		Surgical Prep	clean exterior surgical site	30	₹ 155.00	$ 2.50	$ 0.08	₹ 5.17
Povidone Iodine Solution 5%	5mL	Aurodone	Surgical Prep	clean interior surgical site (anti-infective)	30	₹ 25.00	$ 0.40	$ 0.01	₹ 0.83

Homatropine 2%	5mL	Aurohom	Surgical Prep	Mydriatics and Cycloplegics	30	₹ 29.00	$ 0.47	$ 0.02	₹ 0.97
Proparacaine HCl 0.5%	5mL	Aurocaine	Surgical Prep	Local Anesthetic	30	₹ 45.00	$ 0.73	$ 0.02	₹ 1.50
Sodium Lactate, 500mL (Baxter IV bag)			Intra-op		4	₹ 57.00	$ 0.92	$ 0.23	₹ 14.25
Septidine Drops 5%			Intra-op		30	₹ 25.00	$ 0.40	$ 0.01	₹ 0.83
Hydroxy propyl methyl cellulose solution 2%	3mL	Aurovisc	Intra-op		1	₹ 60.00	$ 0.97	$ 0.97	₹ 60.00
Homatropine 2%	5mL	Aurohom	Post-Op	Mydriatics and Cycloplegics	25	₹ 29.00	$ 0.47	$ 0.02	₹ 1.16
Povidone Iodine Solution 5%	5mL	Aurdone	Post-Op	anti-infective	25	₹ 25.00	$ 0.40	$ 0.02	₹ 1.00
							TOTAL	***$ 1.68***	***₹ 104.06***

Table 3: Changes in Total per-Case GHGs (Greenhouse Gases) in kg CO_2-e, based on variation in inventory items (by inventory category).

Input Variation	*Single-Use Devices Only*	*Reusable Only*	*Waste Treatment Only*	*Formal-dehyde Only*	*Pharma-ceuticals Only*	*Water Only*	*Energy Only*	***Vary All Categories***
-50%	5.4	4.0	6.0	5.9	5.7	5.7	5.4	2.9
-40%	5.5	4.4	6.0	5.9	5.8	5.8	5.5	3.5
-30%	5.6	4.8	5.9	5.9	5.8	5.8	5.6	4.1
-20%	5.7	5.1	5.9	5.9	5.8	5.8	5.7	4.7
-10%	5.8	5.5	5.9	5.9	5.9	5.9	5.8	5.3
Median GHG Value	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
10%	6.0	6.2	5.9	5.9	5.9	5.9	6.0	6.5
20%	6.1	6.6	5.8	5.9	5.9	5.9	6.1	7.1
30%	6.1	7.0	5.8	5.9	6.0	6.0	6.2	7.6
40%	6.2	7.3	5.8	5.9	6.0	6.0	6.3	8.2
50%	6.3	7.7	5.8	5.9	6.0	6.0	6.4	8.8

B. Sensitivity Analyses

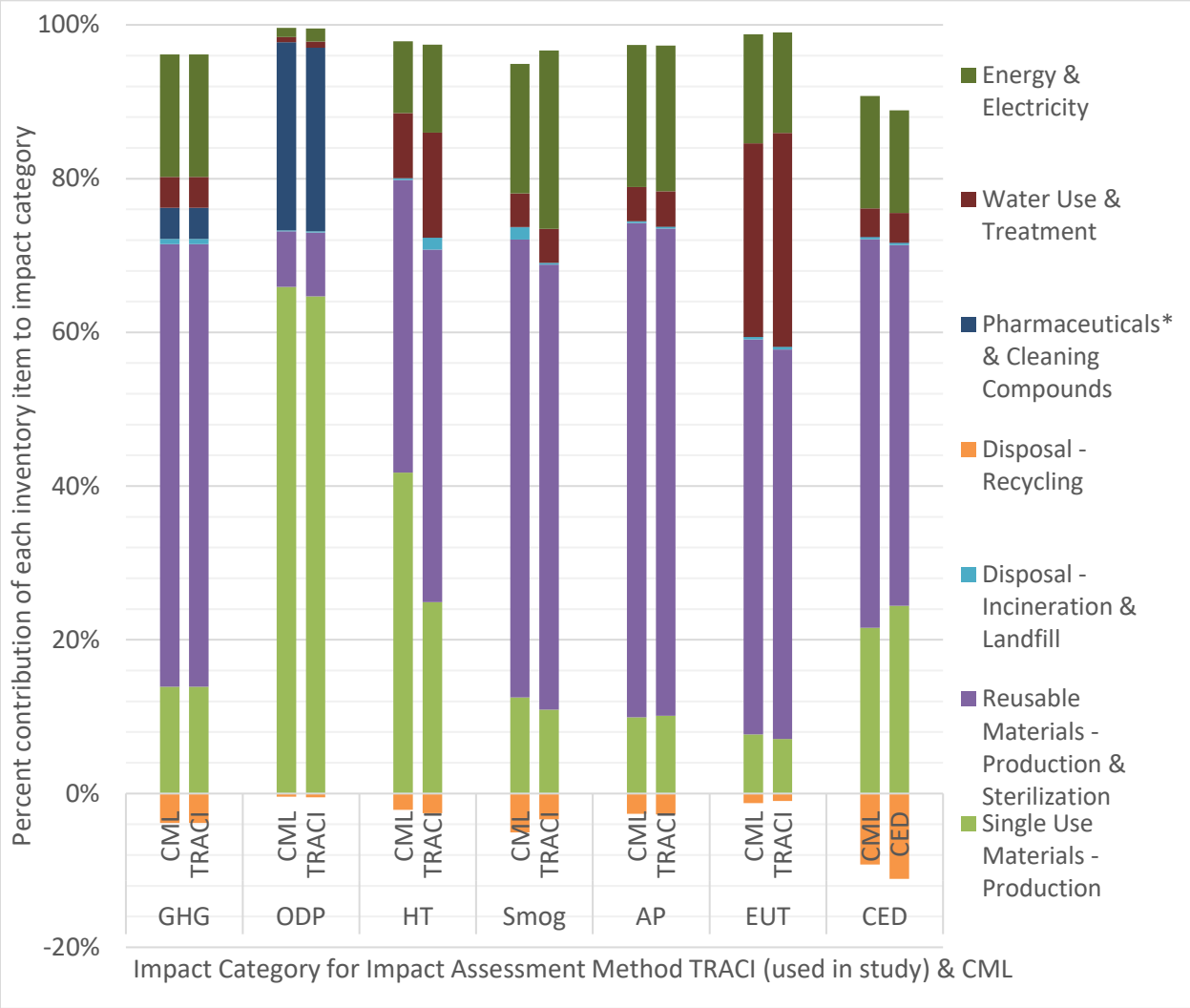

Figure 1: Relative contributions of inventory data to impact categories based on impact assessment method (TRACI or CML).
*GHG = greenhouse gases, ODP = ozone depletion potential, HT = human toxicity (TRACI category is called Carcinogenics), AP = acidification potential, EUT = eutrophication potential, CED = cumulative energy demand (CML category is Abiotic depletion, MJ) *Emissions from pharmaceuticals were conducted using Economic Input-Output LCA (EIO-LCA)[1] which report only in TRACI. TRACI and CML have identical units in the categories of GHGs and ODP, and pharmaceuticals in this comparison are only reported in these two categories.*

Since this study was based in India and there are no impact assessment methods specific to India, we tested two impact assessment methods: TRACI 2.1 v1.02 / US 2008 (The Tool for the Reduction and Assessment of Chemical and other environmental Impacts) by the US Environmental Protection Agency (US EPA)[2] and CML-IA baseline V3.02, World 2000, developed by the Center of Environmental Science of Leiden University.[3] TRACI is commonly used in the United States and was used as the reporting impact assessment for this study to enable future comparisons with US-based cataract surgeries. CML is

typically used in global studies, but as shown here there were no significant differences between the two methods for this study.

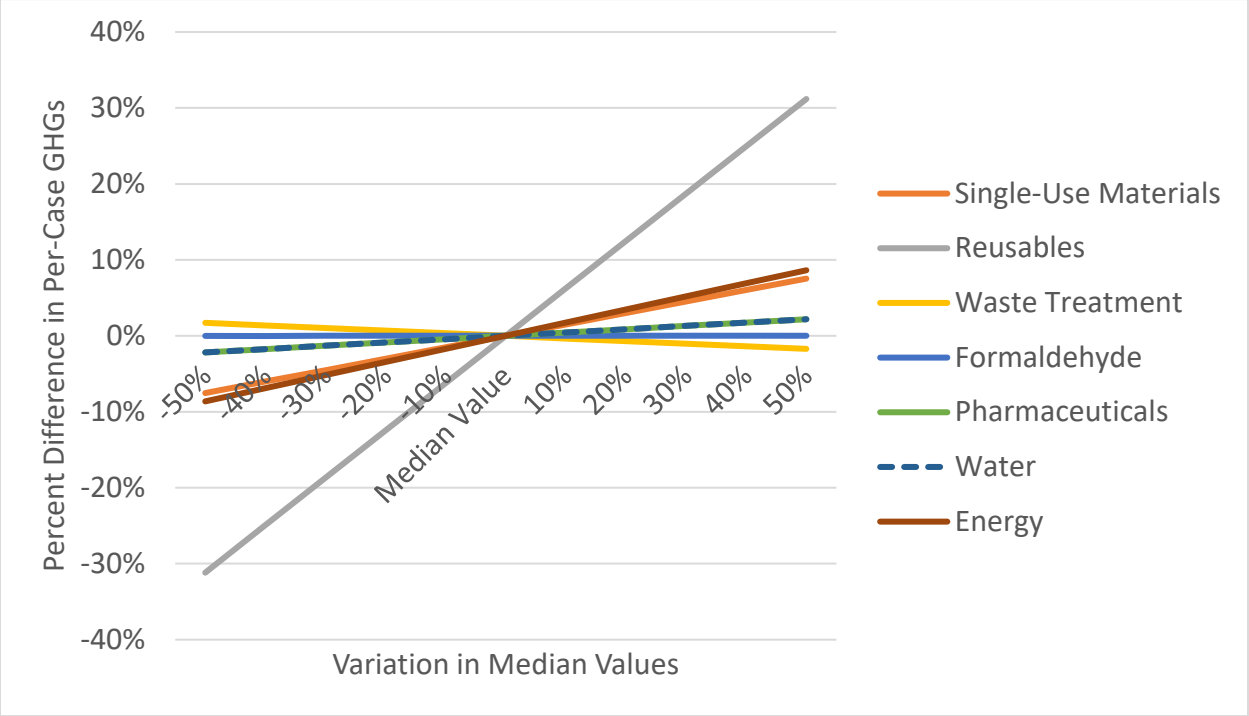

Figure 2: Variation in Total Greenhouse Gas Emissions per Case.

Sensitivity was conducted by varying the input quantity of each inventory item by 10% increments (from -50% of the median, reported value to +50%). Figure 1 summarizes the variation by category. For example, the line for "Single-Use Materials" shows the variation in the overall footprint per case when quantity of single-use materials (only) are increased or decreased. A 10% increase in "single-use materials" represents the summation of a 10% increase in the quantity of each single-use material in the study. Figures 2 through 5 show the changes in GHGs for inventory variation within each category. The top inventory items that create the highest variability in GHGs per case are, in order: (1) Reusable autoclaving, (2) Electricity, (3) Cotton production, (4) Pharmaceuticals, and (5) Polypropylene production.

As shown in Figure 1, variation in "reusables" creates the largest potential changes in GHGs per case. This is due to the autoclaving process and the electricity use from that process (Figures 3 and 5). The inventory value here is 1 instrument tray (so a 50% increase would be 1½ instrument trays). There is a very low probability that a surgical case at Aravind Eye Hospital will require more than one instrument tray, and even then, in absolute numbers using 1½ instrument trays will result in a total of 6.4 kg CO_2-e per phacoemulsification rather than 5.9 kg CO_2-e/case (Table 2).

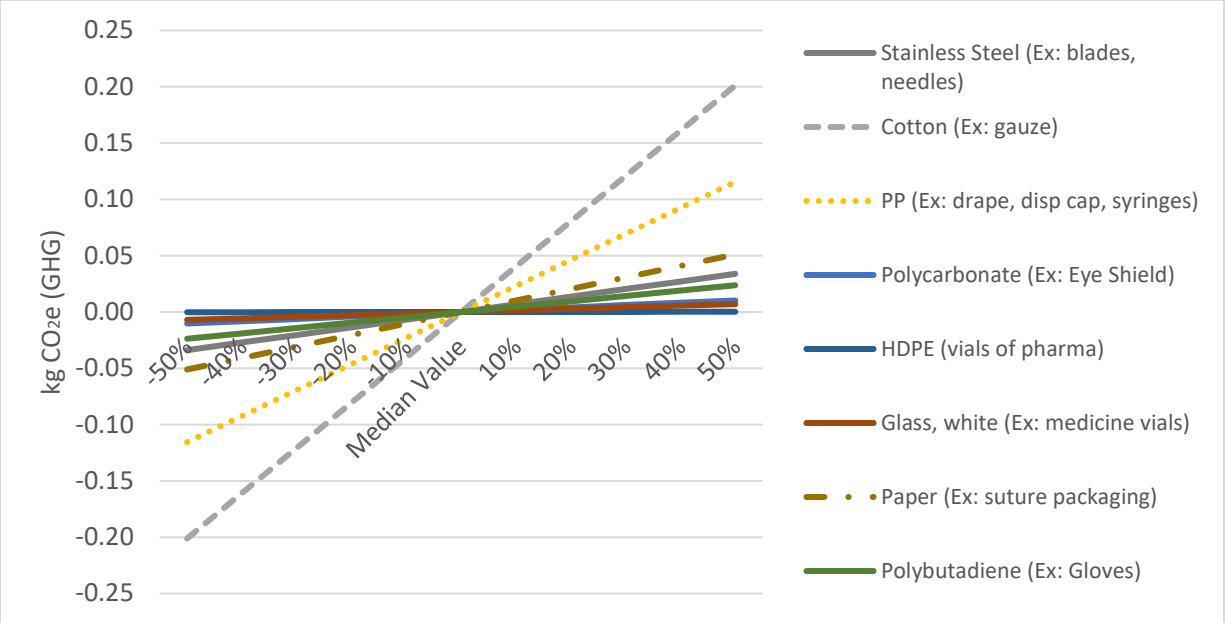

Figure 3: Sensitivity of Single-Use Devices: Variation in Greenhouse Gases (GHG, kg CO_2-e) with Variation of Inventory Quantities.

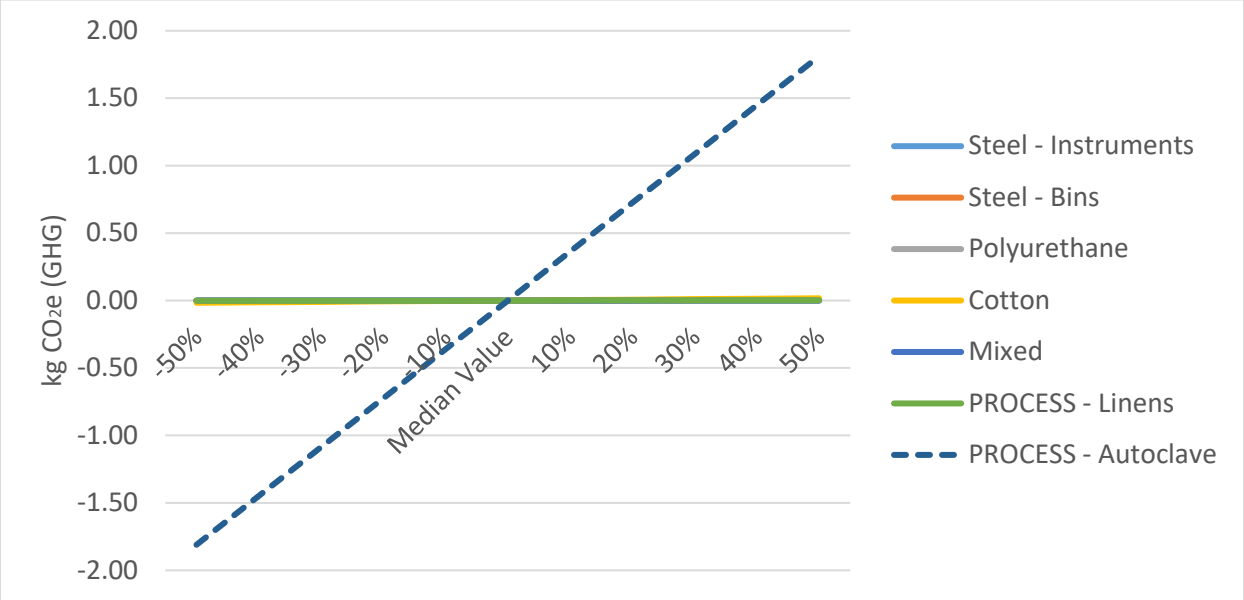

Figure 4: Sensitivity of Reusable Items: Variation in Greenhouse Gases (GHG, kg CO_2-e) with Variation of Inventory Quantities.

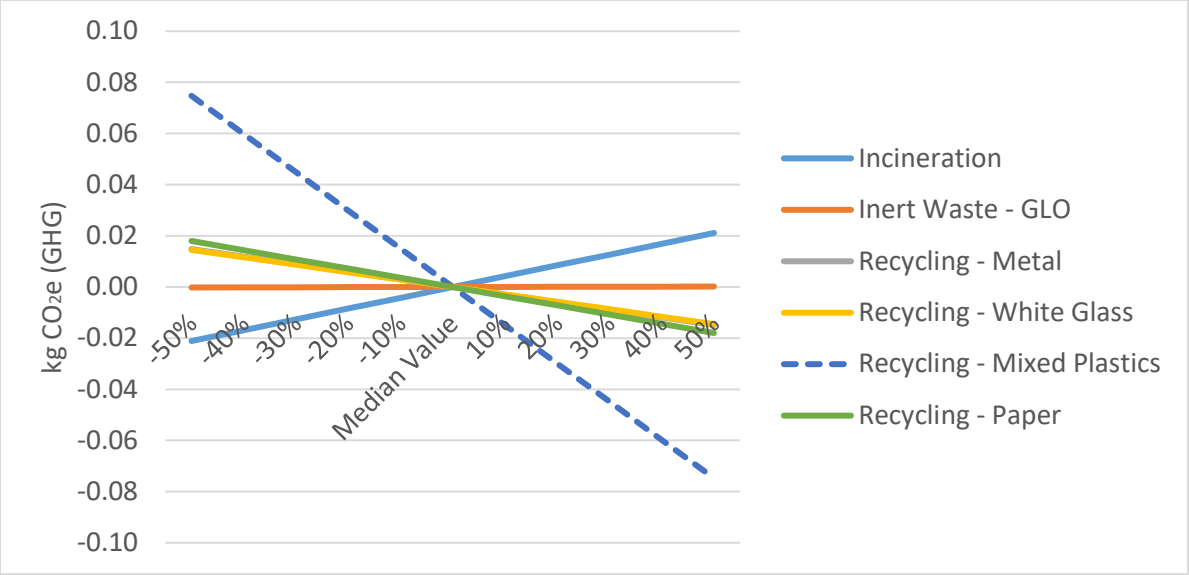

Figure 5: Sensitivity of Waste Treatment: Variation in Greenhouse Gases (GHG, kg CO_2-e) with Variation of Inventory Quantities.

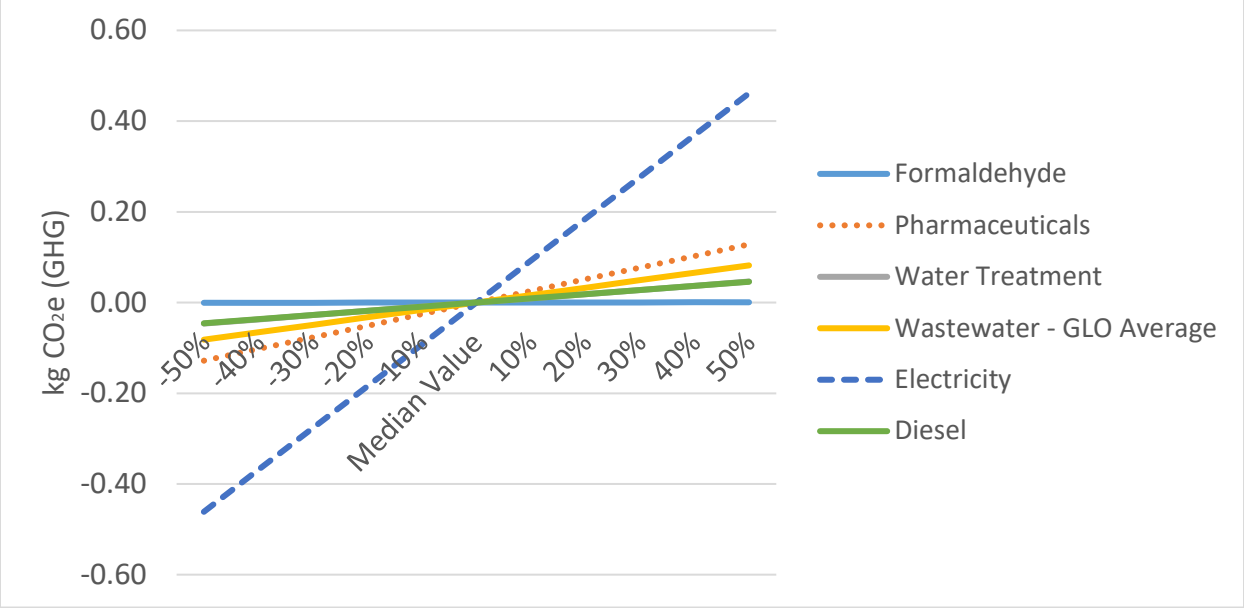

Figure 6: Sensitivity of Pharmaceuticals, Water, and Energy: Variation in Greenhouse Gases (GHG, kg CO_2-e) with Variation of Inventory Quantities.

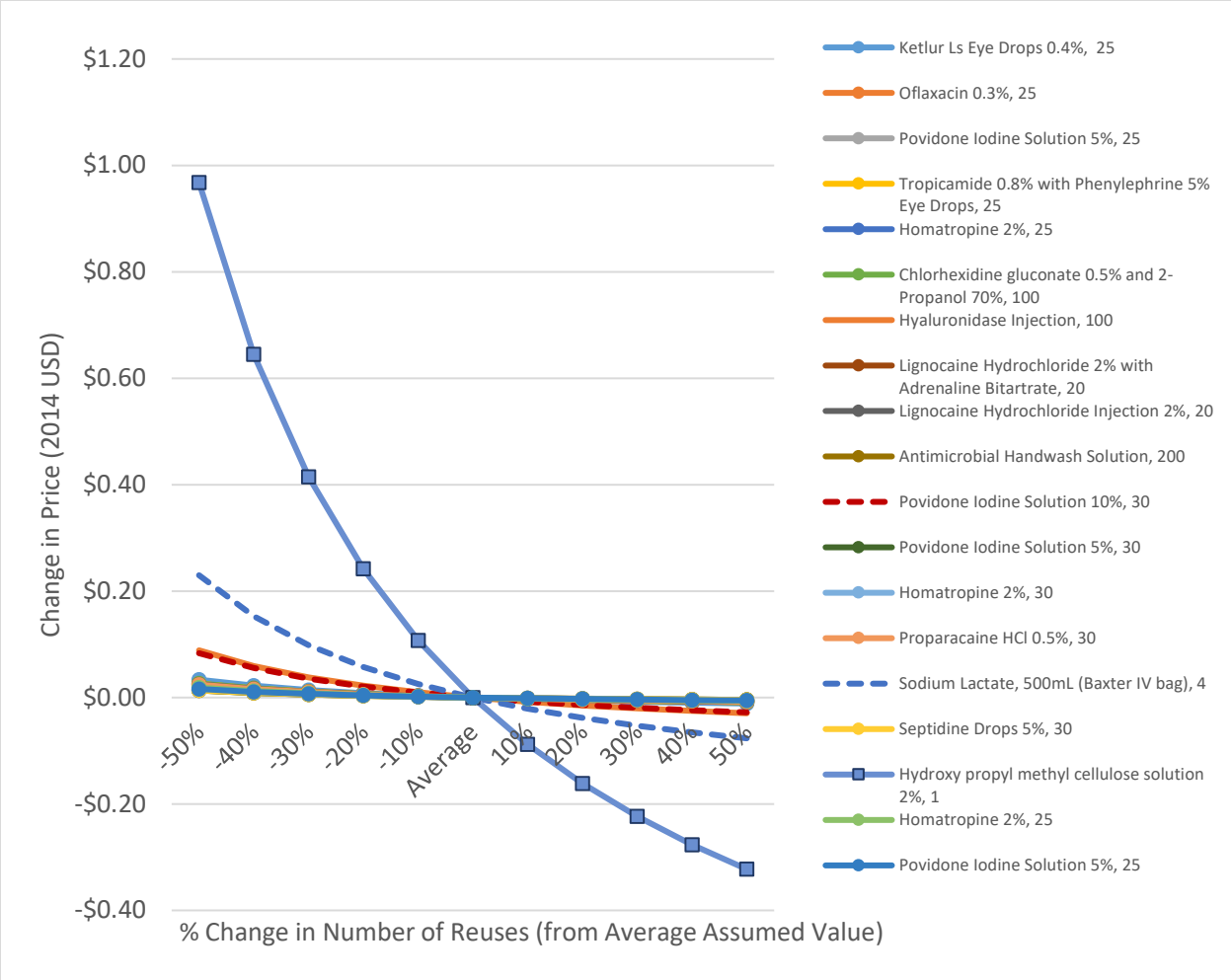

Figure 7: Sensitivity Analysis for Pharmaceuticals Category.
Variation in Prices of Individual Pharmaceuticals (directly correlated with emissions for Economic Input-Output Life Cycle Assessment EIO-LCA methods) based on Changes in the Number of Uses between Disposals. In legend: drug name, average number of uses used in base-LCA. Average cost of all drugs combined is US$1.68.

Pharmaceuticals with largest variation in cost based on lifespan changes are: Hydroxy propyl methyl cellulose solution 2%; Sodium Lactate, 500mL (Baxter IV bag); Hyaluronidase Injection; and Povidone Iodine Solution 10%. Ex: A 50% decrease in the number of uses of hydroxyl propyl methyl cellulose (from 1 use before disposal to ½ use) increases the price per case by nearly US$1.00. A 50% increase in the number of uses (from 1 use before disposal to 1-1/2 uses – or 1 and a half patients per bottle) decreases the price by US$0.32 per case.

Table 4: Life Cycle Assessment Results in Table Form, Average Values of Total Impact Category

*ǂCosts do NOT include staff salaries, the IOL, water use, overhead, or capital equipment; *Pharmaceuticals were calculated using economic data in a US-based model, this did NOT include emissions in eutrophication, carcinogenics, noncarcinogenics, respiratory effects, and ecotoxicity*

		Single Use	Reusable	Reusable	Disposal	Recycling	Pharma	Cleaning Compounds	Water	Energy	Energy	TOTAL
Impact category	Unit	***Single Use Materials - Production***	***Reusable Materials - Production***	***Reusable Materials - Sterilization***	***Materials Disposal - Incineration & Landfill***	***Materials Disposal - Recycling***	***Pharma-ceuticals****	***Cleaning Compounds***	***Water Use & Treatment***	***Electricity***	***Diesel***	***TOTAL***
Ozone Depletion	(kg CFC-11-eq)	1.55E-06	1.27E-07	7.10E-08	3.25E-09	-1.13E-08	5.74E-07	2.88E-10	1.92E-08	1.81E-08	2.25E-08	2.37E-06
Greenhouse Gases	(kg CO_2-eq)	0.89	0.04	3.62	0.04	-0.24	0.26	0.00	0.26	0.92	0.09	5.88
Smog	(kg O_3-eq)	0.05	0.00	0.25	0.00	-0.01	0.02	0.00	0.02	0.06	0.04	0.42
Acidification	(kg SO_2-eq)	4.18E-03	2.01E-04	2.59E-02	9.31E-05	-1.11E-03	1.41E-03	8.96E-06	1.90E-03	6.60E-03	1.20E-03	4.04E-02
Eutrophication	(kg N-eq)	2.50E-03	1.56E-04	1.76E-02	1.25E-04	-3.40E-04	4.29E-05	2.80E-06	9.74E-03	4.48E-03	1.10E-04	3.44E-02
Carcinogenics	(CTUh)	1.00E-07	5.61E-09	1.79E-07	6.19E-09	-1.03E-08	-	5.26E-11	5.48E-08	4.55E-08	5.18E-10	3.81E-07
Non carcinogenics	(CTUh)	1.61E-07	9.21E-09	6.39E-07	5.75E-09	-3.04E-08	-	3.77E-10	9.13E-07	1.63E-07	2.91E-09	1.86E-06
Respiratory Effects	(kg PM2.5-eq)	1.22E-03	7.09E-05	2.80E-02	1.62E-05	-1.96E-04	-	1.12E-06	4.54E-04	7.14E-03	2.06E-04	3.69E-02
Ecotoxicity	(CTUe)	8.21E+00	5.40E-01	1.68E+01	2.22E-01	-1.02E+00	-	1.18E-02	5.58E+00	4.27E+00	5.15E-02	34.63
Cumulative Energy Demand	(MJ)	21.47	0.60	4.06E+01	0.21	-9.76	3.96	0.05	3.38	10.35	1.40	72.29
Costǂ	(USD, $)	8.33	2.19	0.00	0.04	-0.04	1.68	0.00	0.00	0.04	0.01	12.25

Table 5: Life Cycle Assessment Results in Table Form, Percentage of Total Impact Category

*ǂCosts do NOT include staff salaries, the IOL, water use, overhead, or capital equipment; *Pharmaceuticals were calculated using economic data in a US-based model, this did NOT include emissions in eutrophication, carcinogenics, noncarcinogenics, respiratory effects, and ecotoxicity*

		Single Use	Reusable	Reusable	Disposal	Recycling	Pharma	Cleaning Compounds	Water	Energy	Energy
Impact category	Unit	***Single Use Materials - Production***	***Reusable Materials - Production***	***Reusable Materials - Sterilization***	***Materials Disposal - Incineration & Landfill***	***Materials Disposal - Recycling***	***Pharma-ceuticals****	***Cleaning Compounds***	***Water Use & Treatment***	***Electricity***	***Diesel***
Ozone Depletion	(kg CFC-11-eq)	65%	5%	3%	0%	0%	24%	0%	1%	1%	1%
Greenhouse Gases	(kg CO_2-eq)	15%	1%	62%	1%	-4%	4%	0%	4%	16%	2%
Smog	(kg O_3-eq)	11%	0%	58%	0%	-3%	6%	0%	4%	15%	9%
Acidification	(kg SO_2-eq)	10%	0%	64%	0%	-3%	3%	0%	5%	16%	3%
Eutrophication	(kg N-eq)	7%	0%	51%	0%	-1%	0%	0%	28%	13%	0%
Carcinogenics	(CTUh)	26%	1%	47%	2%	-3%	-	0%	14%	12%	0%
Non carcinogenics	(CTUh)	9%	0%	34%	0%	-2%	-	0%	49%	9%	0%
Respiratory Effects	(kg PM2.5-eq)	3%	0%	76%	0%	-1%	-	0%	1%	19%	1%
Ecotoxicity	(CTUe)	24%	2%	48%	1%	-3%	-	0%	16%	12%	0%
Cumulative Energy Demand	(MJ)	30%	1%	56%	0%	-14%	5%	0%	5%	14%	2%
*Cost*ǂ	(USD, $)	68%	18%	0%	0%	0%	14%	0%	0%	0%	0%

C. Bibliography for Supplemental Information

1. Carnegie Mellon University Green Design Institute. Economic Input-Output Life Cycle Assessment (EIO-LCA) US 2002 (428) model. 2013 [cited April 18, 2013]Available from: http://www.eiolca.net

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3. Sleeswijk AW, van Oers LF, Guinée JB, Struijs J, Huijbregts MA. Normalisation in product life cycle assessment: An LCA of the global and European economic systems in the year 2000. *Sci Total Environ* 2008, **390**(1)**:** 227-240.