Life-Cycle Analysis of Orbio® os3

Evaluation of os3 vs Conventional Daily-Use Cleaning Chemicals in Select Cleaning Scenarios

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Prepared for:

ORBIO® TECHNOLOGIES
A Tennant Company Group

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This analysis and report was prepared for Orbio Technologies by Ecoform, an environmental consulting firm committed to the design, evaluation, and adoption of clean products and materials through technical and policy research.

Results and conclusions of this report are based on data provided to Ecoform for os3 by Orbio and its suppliers. This analysis would not have been possible without the cooperation of individual Orbio suppliers and partners who voluntarily provided data and confidential business information in support of this effort. Ecoform staff would like to thank Orbio and its partners for their cooperation and assistance in this analysis. Please direct any questions or enquiries about this report to the following:

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OVERVIEW OF LIFE-CYCLE ASSESSMENT

Orbio Technologies Group (Orbio) was established in 2009 to execute Tennant Company's vision of becoming the global leader in sustainable cleaning technologies. Orbio is dedicated to developing and marketing On-Site Generation (OSG) technologies that will set the standard for sustainable cleaning around the world. With the rapidly growing emphasis on green building and human health, the market is increasingly demanding cleaning systems that reduce or eliminate our dependence on conventional cleaning chemicals.

To meet this demand, Orbio developed and launched in 2012 the 5000-Sc, a breakthrough product based on the Orbio® On-Site Generation that produced on-site a multi-purpose cleaning solution using tap water, electricity, and salt. The product not only reduced environmental impacts across the life-cycle from the off-site production and transport of more complicated conventional packaged chemical systems, but also eliminated packaging waste. Now, Orbio has developed the next generation of On-Site Generation technology. The Orbio os3, a smaller, more flexible system that produces both cleaning and disinfecting solutions, fits in most janitorial closets.

Orbio has contracted with Ecoform to fully evaluate the relative life-cycle benefits associated with the use of the os3 as compared to conventional daily-use cleaning chemicals in select cleaning scenarios.

OS3 DESCRIPTION

Through electrolysis, the os3 uses salt, softened water and electricity to produce two solutions – free available chlorine, in the form of hypochlorous acid (HOCl), and a low concentration of sodium hydroxide (NaOH). During the electrolytic process, softened tap water and a salt brine solution are separated by an ion exchange membrane into two solutions: MultiSurface *Concentrate*, and MultiMicro™ *Concentrate*. These concentrated solutions are held inside separate tanks in the os3 generator until they are diluted with softened water and dispensed as ready-to-use (RTU) solutions through the os3 dispenser. The os3 is shown at right. Specifications for the generator output are displayed in appendix Table C3.

Figure 1: os3 Dispenser

The MultiMicro *200*[1] solution replaces conventional disinfectants. It is suitable for use on surfaces such as glass, ceramic, laminate, painted, and other surfaces. MultiMicro *200* can be delivered as a coarse spray through spray bottles, mop buckets, flat microfiber mop systems, or other similar equipment.

[1] MultiMicro *200* refers to MultiMicro *Concentrate* that has been diluted by the Orbio os3 dispenser to the ready-to-use form containing 200 ppm free available chlorine

The MultiSurface *Cleaner* replaces conventional all-purpose cleaners, glass cleaners in spray bottles, stainless steel cleaners, and chemicals used in automatic floor and carpet cleaning equipment. It can be used on a variety of surfaces including glass, metal, sealed concrete and stone, ceramic, laminate, plastic, various hard floor surfaces, and carpets.

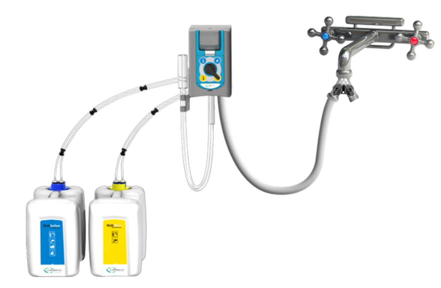

Figure 2: os3 Satellite

The os3 system is comprised of a generator, water softener, and dispenser. It can be expanded with the addition of optional Orbio® Satellite Systems, pictured in Figure 2, that allow MultiSurface *Concentrate* and MultiMicro™ *Concentrate* to be transported to remote location within the facility, diluted, and dispensed using processes that are very similar to those used to distribute conventional packaged chemical concentrates.

LIFE-CYCLE ASSESSMENT SCOPE

Life-Cycle Approach

Life-cycle impacts in a variety of human health and environmental categories resulting from the cleaning of select building types were evaluated in a comparative life-cycle assessment. Three separate cleaning scenarios were evaluated, each based on data from actual building maintenance operations associated with each facility type. For each scenario, the impacts associated with the production, transportation and disposal of the cleaning solutions and their associated packaging were calculated to assess the environmental and human health performance of the Orbio os3 as compared to the use of conventional packaged cleaning chemicals. Because cleaning operations are independent of the manner in which the cleaning solutions are produced, other cleaning materials such as paper towels and cleaning clothes were scoped out of the comparative study, the effect of which is considered to be minimal. The scope of the study is depicted in Figure 3.

The life-cycle analysis was performed using version 6 of the GaBi Life-Cycle Software. Secondary data from GaBi and Ecoinvent datasets, supplemented by proprietary Ecoform data sets, comprised the entirety of the life-cycle inventory data. Sample GaBi model diagrams are presented in Appendix A. Specific impact categories evaluated are described in Appendix B.

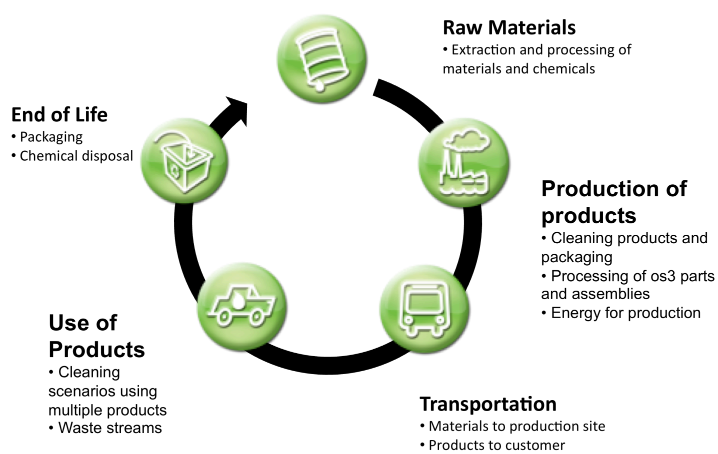

Figure 3: Scope of LCA Analysis

Overall, data quality is considered good for this analysis, given that there were no significant data gaps. Overall, 97% of the total mass of the os3 was characterized in this assessment. Sensitivity analyses were conducted around these potential gaps, with minimal affect on the overall disparity in the impacts. As such, the overall confidence in the study is evaluated to be good.

Life-Cycle Scenarios

Individual life-cycle scenarios were constructed to assess the life-cycle performance of the Orbio® os3 relative to cleaning using conventional daily-use chemicals. Scenarios characterize the critical parameters associated with building maintenance operations and are used to define a functional unit for the study. Specific parameters for each of the scenarios evaluated in this study are presented in the Table 1.

Table 1. Life-Cycle Scenario – Building Types

Parameter	Life-Cycle Evaluation Scenarios		
	Rehabilitation Hospital	Community College	Four Year University
Total Facility Size (sq ft)	600,000	340,000	3.2 million
Floor Area Cleaned (sq ft)	400,000	250,000	2 million
Carpet/Hard Floor Split (%)	10/90	40/60	40/60
Hard Flooring Type	Terrazo/VCT	Terrazo/ VCT/Polished Concrete	Terrazo/ VCT/Polished Concrete
Cleaning Staff (# of workers)	36	11	110
Traffic/Use	180 patient rm/60 rest rm/8 labs	1,300 students	11,000 students
Equipment	2 os3+ 3 Satellites	os3+ 3 Satellites	12 os3+ 24 Satellites

The ***functional unit*** for the LCA for each scenario is defined as the production and transportation of solutions sufficient in volume to effectively clean and disinfect the indoor building space defined in each individual scenario over the period of five years. For example, the functional unit for the Four Year University scenario would be the production and transportation of cleaning solutions sufficient to clean 3.2 million square feet of enclosed building space used for the purposes of higher education for five years under the conditions described in Table 1. For the purposes of this study, cleaning operations were considered to include the need for floor, glass, all-purpose, and carpet pre-spray cleaners, as well as disinfectants and their associated cleaning operations. The five-year period was selected to reflect a conservative estimate of the expected durability of the os3.

Chemical usage data collected from actual cleaning operations on buildings identical to those described in each of the scenarios, along with key parameters such as water and energy consumption, and operating time were used to compile a bill of materials (BOM) for both the Orbio os3 and for the system of conventional cleaning chemicals and disinfectants. The BOMs used for this study, as well as tables containing the key parameters and data for this study are presented in Appendix C.

Life-cycle Inventory Analysis

The Life-cycle Inventory Analysis covers the life-cycle stages as shown in Figure 4.

Materials
Includes raw materials and extraction processes for all chemicals and materials identified in BOMs.

Production
Production of individual ORBIO os3 components as well as all chemical products and packaging are evaluated. No assembly processes are included.

Transport
Transport from suppliers to final use is modeled. Average transport profile for U.S. is assumed

Use
Includes use of ORBIO os3 and chemical products under different cleaning scenarios. Energy and water use are also included.

End of Life
ORBIO os3 is considered reclaimed under this scenario, consistent with current business model. All packaging considered to be disposed in landfill.

Figure 4. Inventory Scope by Life-Cycle Stage

LIFE-CYCLE IMPACT ASSESSMENT

Impacts to a variety of key environmental and resource categories for the two compared systems are presented for selected cleaning scenarios. Results reflect impacts associated with the life-cycle product chain consistent with the scope of the inventory data. Detailed descriptions of individual impact categories are described in the Appendix B.

Rehabilitation Hospital Scenario

Life-cycle impacts assessed for both the os3 and conventional daily-use chemical cleaners and disinfectants are presented in Table 2. Results are based on the rehabilitation hospital scenario and functional unit, which specifies that enough cleaning and disinfecting agents be produced to clean a 600,000 square foot health care facility for a period of 5 years. Two os3 generators and three satellite stations were evaluated, a configuration recommended by Orbio® for this scenario. Results are limited to cleaning tasks performed with all-purpose, carpet, glass, and floor cleaners, and disinfectants. Results have been normalized, and the percent differences have been presented in Table 3 and visually depicted in Figure 5.

The cleaning operations performed in the maintenance of the rehabilitation hospital facility consumed a significant volume of chemicals, totaling 5,960 gallons of conventional daily-use chemical product concentrates at various dilution levels. A breakdown of chemical product use is presented in Tables 8 and 9. Results indicate that on-site generation of cleaning solutions with the Orbio os3 is clearly preferential to the distribution and use of conventional daily-use cleaning chemicals. Environmental and human health impacts ranged from 55-95 percent better than those for conventional chemicals. This is directly related to the large volumes of all types of chemicals used in this cleaning scenario, as well as to a chemical product profile with an overall high average dilution rate of 2.4 ounces per gallon (see Table 9). Additional analysis of the impacts associated with this scenario is presented later in this report.

Table 2. Life-Cycle Impacts – Rehabilitation Hospital

LCA Categories		Conventional Cleaners	os3	Benefit (%)
Acidification	(kg SO_2)	71.1	21.7	**70**
CO_2 Emissions	(kg CO_2)	23,800	4,680	**80**
Ecotoxicity	(ton TEQ eq)	59,000	26,600	**55**
Eutrophication	(kg PO4)	1.89	0.168	**91**
Ozone Depletion	(g CFCs)	4.24	0.198	**95**
Particulate	(kg PM2.5)	17.0	3.55	**79**
Smog	(kg NOx)	0.0527	0.00901	**83**

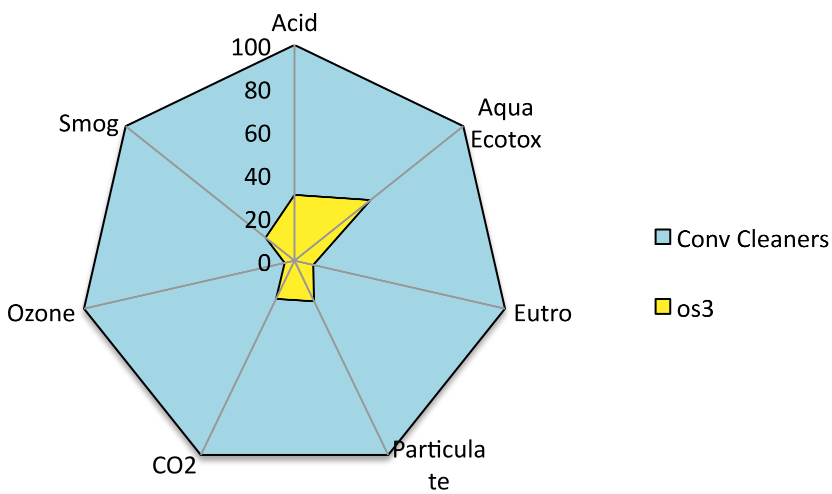

Figure 5. Chart of Relative Impacts – Rehabilitation Hospital

Calculation of a series of equivalent offsets (e.g. car emissions offset) for specific categories such as CO_2 emissions provide additional context for the relative results of the life-cycle comparison. Offsets are calculated by comparing the net improvement in a particular category (e.g. energy consumption) to established factors such as the energy content of coal, or emissions from an airplane. The accumulated benefits of the os3 expressed in common equivalent offsets are presented in Table 3.

Table 3. Equivalent Offsets per os3 – Rehabilitation Hospital

Category	Savings 1 Year	Savings 5 year	Equivalent Offsets (per facility)
Energy (MJ)	53,260	266,300	Barrels of Oil Offset (5 yr) – 43 barrels Months of Household Energy Offset (5 yr) – 78 months Number of Households Offset (5 yr) – 6.5 households Gallons of Gasoline Offset (5 yr) – 2,030 gallons
CO_2 Emissions (kgCO2)	3,820	19,100	Months of Passenger Car Travel (5 yr) – 49.6 months Number of Cars Offset (5 yr) – 4.1 cars

According to the American Hospital Association, there are 5,723 registered hospitals in the U.S. Were 40 percent of these Hospitals to use an Orbio® os3 system to produce the on-site cleaning solutions required to support building maintenance operations for 365 days per year, collectively they would save enough energy annually to power more than 2,990 homes annually and offset the yearly global warming emissions of more than 1,890 passenger cars.

Community College Scenario

Life-cycle impacts assessed for both the os3 and conventional daily-use chemical cleaners and disinfectants are presented in Table 3. Results are based on the Community College scenario and functional unit, which specifies that enough cleaners and disinfectants be produced to clean a 340,000 square foot campus for a period of 5 years. One os3 generator and three satellite stations were evaluated in this scenario. Results are limited to cleaning tasks performed with all-purpose, carpet, and floor cleaners, and disinfectants. Results have been normalized, and the percent differences have been presented in Table 4, and visually depicted in Figure 6.

Table 4. Life-Cycle Impacts – Community College

LCA Categories		Conventional Cleaners	os3	Benefit (%)
Acidification	(kg SO_2)	13.1	13.2	**0**
CO_2 Emissions	(kg CO_2)	4,300	2,830	**34**
Ecotoxicity	(ton TEQ eq)	14,600	15,400	**-5**
Eutrophication	(kg PO4)	0.285	0.103	**64**
Ozone Depletion	(g CFCs)	0.468	0.118	**75**
Particulate	(kg PM2.5)	3.09	2.15	**31**
Smog	(kg NOx)	0.00923	0.00544	**41**

In the Community College scenario, a total of 1,670 gallons of conventional daily-use chemical product concentrates were used, a total significantly less than that of either of the other scenarios evaluated in this analysis. A breakdown of the chemical products used is presented in Table 5. However, unlike the previous Rehabilitation Hospital scenario, a greater percentage of the conventional chemical products were highly concentrated, leaving a fairly low average chemical dilution rate of 1.2 ounce per gallon. As a result, while the os3 performed significantly better in five of the impact categories exhibiting benefits ranging from 31-64 percent, it performed at relative parity in both the acidification and ecotoxicity categories. However, on balance, the significant benefits over the large majority of categories and their scale outweigh the slight increase experienced in the ecotoxicty category.

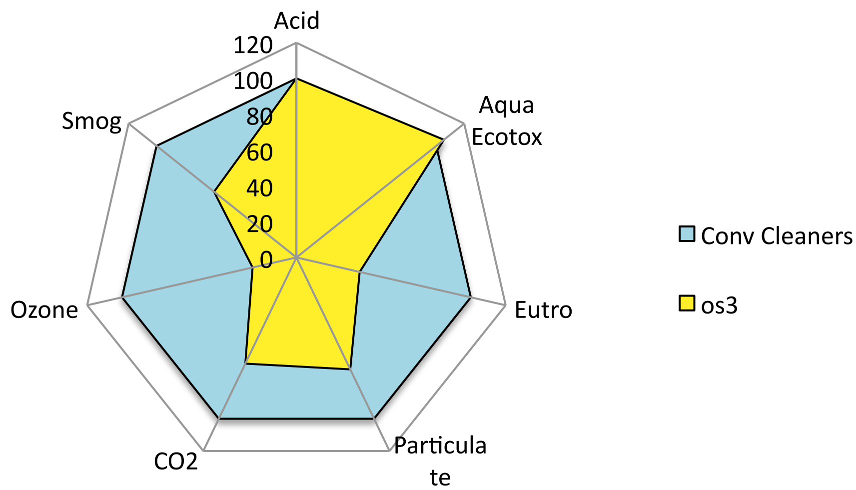

Figure 6. Chart of Relative Impacts – Community College

Calculation of a series of equivalent offsets (e.g. car emissions offset) for specific categories such as CO_2 emissions provide additional context for the relative results of the life-cycle comparison. Offsets are calculated by comparing the net improvement in a particular category (e.g. energy consumption) to established factors such as the energy content of coal, or emissions from an airplane. The accumulated benefits of the os3 expressed in common equivalent offsets are presented in Table 5.

Table 5. Equivalent Offsets per os3 – Community College

Category	Savings 1 Year	Savings 5 year	Equivalent Offsets (per facility)
Energy (MJ)	3,660	18,300	Barrels of Oil Offset (5 yr) – 3 barrels Months of Household Energy Offset (5 yr) – 5.4 months Number of Households Offset (5 yr) – 0.5 households Gallons of Gasoline Offset (5 yr) – 140 gallons
CO_2 Emissions (kgCO2)	295	1,470	Months of Passenger Car Travel (5 yr) – 3.8 months Number of Cars Offset (5 yr) – 0.32 cars

According to the U.S. Department of Education, there are an estimated 1,729 Community Colleges in the U.S in 2010. Were 40 percent of these Community Colleges to use an Orbio® os3 to produce the on-site cleaning solutions required to support building maintenance operations for 260 days per year, collectively they would save enough energy annually to power more than 62 homes annually and offset the yearly global warming emissions of more than 44 passenger cars.

Four Year University Scenario

This scenario is similar to the previous Community College scenario, only on a much larger scale. Results are based on the Four Year University scenario and functional unit, which specifies that enough cleaners and disinfectants be produced to clean a 3.2 million square foot campus for a period of 5 years. Life-cycle impacts assessed for both the os3 and conventional daily-use chemical cleaners and disinfectants are presented in Table 3. Given the large scale of the Four Year University scenario, 12 os3 generators and 24 satellite stations were recommended and evaluated in this scenario. Results are limited to cleaning tasks performed with all-purpose, carpet, and floor cleaners, and disinfectants. Results have been normalized, and the percent differences have been presented in Table 6, and visually depicted in Figure 7.

Table 6. Life-Cycle Impacts – Four Year University

LCA Categories		Conventional Cleaners	os3	Benefit (%)
Acidification	(kg SO_2)	145	153	**-6**
CO_2 Emissions	(kg CO_2)	47,300	33,500	**29**
Ecotoxicity	(ton TEQ eq)	161,000	179,000	**-11**
Eutrophication	(kg PO4)	3.14	1.52	**52**
Ozone Depletion	(g CFCs)	5.15	1.43	**72**
Particulate	(kg PM2.5)	34.1	25.9	**24**
Smog	(kg NOx)	0.102	0.0646	**36**

The cleaning operations performed in the maintenance of the Four Year University campus consumed 18,370 gallons of conventional daily-use chemical product concentrates, greater than three times the amount for the health care scenario and more than ten times that used for a Community College. A breakdown of chemical product use is presented in Table 5. The Orbio® os3 is clearly preferential under this scenario, displaying benefits in five of the seven evaluated environmental and human health categories ranging from 24-72 percent. Like the Community College scenario, the system also exhibited modest disadvantages in both acidification and ecotoxicity, mostly attributable to the high percentage of highly concentrated cleaners used in the scenario. However, on balance the os3 results are clearly better given the benefits realized in the majority of impact categories and the relative scale of those benefits.

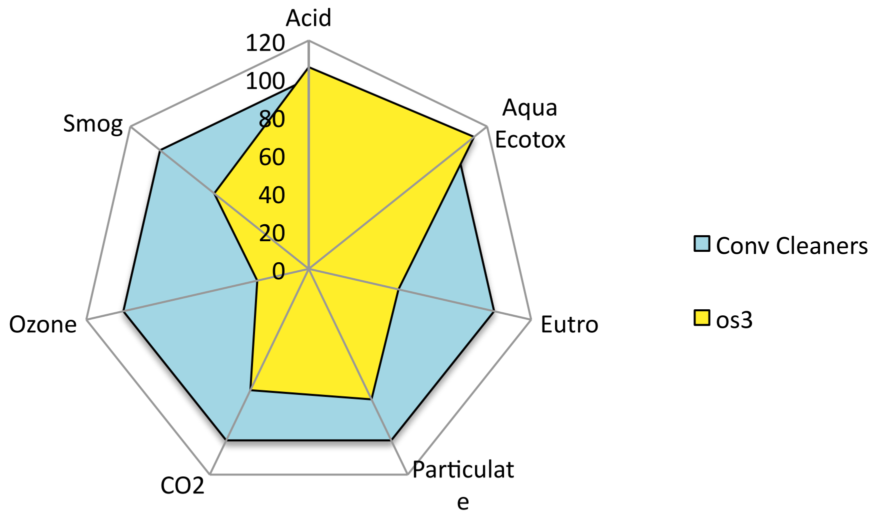

Figure 7. Chart of Relative Impacts – Four Year University

Calculation of a series of equivalent offsets (e.g. car emissions offset) for specific categories such as CO_2 emissions provide additional context for the relative results of the life-cycle comparison. Offsets are calculated by comparing the net improvement in a particular category (e.g. energy consumption) to established factors such as the energy content of coal, or emissions from an airplane. The accumulated benefits of the os3 expressed in common equivalent offsets are presented in Table 7.

Table 7. Equivalent Offsets per os3 – Four Year University

Category	Savings 1 Year	Savings 5 year	Equivalent Offsets (per facility)
Energy (MJ)	33,500	167,600	Barrels of Oil Offset (5 yr) – 27 barrels Months of Household Energy Offset (5 yr) – 49 months Number of Households Offset (5 yr) – 4.1 households Gallons of Gasoline Offset (5 yr) – 1,280 gallons
CO_2 Emissions (kgCO2)	2,770	13,800	Months of Passenger Car Travel (5 yr) – 36 months Number of Cars Offset (5 yr) – 3 cars

According to the National Center for Education Statistics, there were an estimated 2,870 degree-granting universities in the U.S. in 2010. Were 40 percent of these University campuses to use an Orbio® os3-based system to produce the on-site cleaning solution required to support building maintenance operations for 260 days per year, collectively they would save enough energy annually to power more than 942 homes annually and offset the yearly global warming emissions of more than 690 passenger cars.

ANALYSIS OF LCA RESULTS

Results of the life-cycle impact assessment demonstrate clearly the significant environmental benefits associated with the use of the os3. In each of the scenarios considered, the Orbio® os3 was better in the majority of human health and environmental categories, making it clearly the better choice from an environmental and human health perspective. Understanding why the relative performance of Orbio os3 is better requires a deeper analysis into the performance of the system and the drivers of that performance.

Volume of Cleaning Solution and Dilution Rate

The functional unit for this study was defined earlier in this report as the production of the volume of cleaning solution required to support the cleaning and maintenance operations for each of the various scenarios for a period of five years. To inform this analysis, chemical usage data from building and maintenance operations performed with conventional chemical cleaners and disinfectants were used as a basis for the life-cycle modeling. The quantity and type of chemical cleaner and disinfectant consumed over a five-year period for each scenario is presented in Table 8, along with the dilution rate for each product type.

Table 8. Life-Cycle Scenario – Conventional Daily Use Cleaning Products (gals Conc./5 yr)

Product	Life-Cycle Evaluation Scenarios		
	Rehabilitation Hospital	Community College	Four Year University
Glass Cleaner (Diluted 12 oz to 1 gal)	157	72	792
Daily Floor Cleaner (Diluted 1 oz to 1 gal)	855	1,112	12,232
All-Purpose Cleaner (Diluted 4 oz to 1 gal)	2,855	241	2,651
Carpet Pre-Spray (Diluted 10 oz to 1 gal)	1,298	60	660
Disinfectant (Diluted 1 oz to 1 gal)	799	185	2,035

Cleaning products are routinely concentrated to save packaging costs and to limit impacts from transportation. Each of the cleaning products in this analysis requires on-site dilution to achieve the recommended working concentration for proper cleaning performance, with dilution rates ranging from 1 ounce to 12 ounces per gallon of cleaning or disinfecting solution, depending on the product. Table 9 presents the total volume of cleaning chemical consumed for each scenario, along with an average dilution rate over the entire chemical use profile.

Table 9. Average Dilution Rate of Conventional Daily-Use Cleaners - By Scenario

Scenarios	Conventional Cleaner Conc. (gal)	Dilution Water (gal)	Diluted Chemical Cleaner Sol'n (gal)	Avg Dilution (oz/gal)
Health Care	5,960	321,400	327,300	**2.4**
Community College	1,670	175,300	176,900	**1.2**
Four Year University	18,370	1,928,000	1,946,000	**1.2**

To identify and better understand the correlation between the various factors presented and the results of this LCA, the relative benefits associated with the on-site production of chemicals using the Orbio® os3 are presented in Table 10. These results reflect the relative differences in impact scores presented earlier in this LCA under each scenario.

Table 10. Relative Benefits Associated with os3, in % improvement

Impact Category46	**Relative % Life-Cycle Benefits**		
	Rehabilitation Hospital	**Community College**	**Four Year University**
Acidification	70	0	-6
CO2 Emissions	80	34	29
Ecotoxicity	55	-5	-11
Eutrophication	91	64	52
Ozone Depletion	95	75	72
Particulate	79	31	24
Smog	83	41	36

The calculation of an average dilution rate for each scenario in the Table 13 provides insight into the relative impacts of the alternatives. It is the average dilution rate, and not the total volume of chemical concentrate products that is the primary driver of the results. For example, were the driver to be total volume of chemical concentrate, we would expect the Four Year University scenario to yield the highest comparable benefits, as it uses a greater volume of chemical concentrates than in those used for the Rehabilitation Hospital scenario, thus providing a greater footprint for the os3 to offset. However, despite using nearly 3 times the amount of chemical concentrate volume, the benefits associated with the use of the Orbio os3 in the Four Year University scenario are less than those realized for the Rehabilitation Hospital. In fact, the Rehabilitation Hospital results are also better than those realized for the Community College scenario which used less chemical concentrate. Together, this demonstrates that It is the higher dilution rate associated with the Rehabilitation Hospital scenario that is more predicative of environmental benefit.

Dilution rate is a critical factor in the comparative analysis, in large part because it has the greatest influence on the primary drivers of impacts for the Orbio® os3, those being energy consumption and water use. Highly concentrated chemicals minimize the impacts associated with transportation and packaging for the chemical alternative, while resulting in a larger volume of cleaning solutions, a volume that the os3 must run longer and consume more energy to match in terms of production. As can be seen in the table, as the average dilution rate of the chemicals increases (i.e., concentration decreases) over the entire chemical profile, so does the relative effectiveness of the Orbio os3. This relationship has been confirmed through sensitivity analysis where the dilution rate was varied for multiple scenarios, and the correlation was confirmed. This suggests that there may be a pivotal value, or range of values, over which the os3 becomes preferential. However, other factors play a role in this determination such as overall mass and energy consumption, both of which are discussed below.

Effect of Mass

When comparing alternatives using life-cycle assessment, the results often correspond with the overall mass of materials required for each alternative, especially in comparisons with a large disparity in mass over the period of the analysis. In this case, evaluation of the overall mass involves totaling the mass of the Orbio os3 and its satellites, salt, and wear items, compared to the overall mass of the chemical products and their associated packaging. These values are reflected in the Bill of Materials for each of the systems presented in Appendix C of this report. The total mass from the various BOMs is summarized in Table 11.

While dilution rate is the primary driver of relative life-cycle impacts, the mass of materials associated with each system plays a small role in the overall life-cycle benefits, especially in situations with low chemical usage. Each pound of material utilized incurs impacts throughout the life-cycle of that material including those associated with the extraction and processing of the material, its transportation and manufacture, through it use, and to its eventual disposition at end-of-life. These impacts can be significant depending on the material, and are often more influential on a comparative basis than impacts during other stages.

Table 11. Material Mass By Scenario

System	Life-Cycle Evaluation Scenarios (kg)		
	Rehabilitation Hospital	Community College	Four Year University
Orbio os3 (w satellites)			
Total Materials	1,116	744	8,145
Water	1,250,000	704,000	7,744,000
Total Materials/Resources	**1,251,000**	**704,800**	**7,752,000**
Conventional Products			
Total Materials	23,670	6,628	72,900
Water (for dilution)	1,169,000	637,300	7,011,000
Total Materials/Resources	**1,192,000**	**643,900**	**7,083,000**

It can be seen in Table 11 that the Orbio® os3 utilizes less material, excluding water, than conventional chemicals across all scenarios. Differences in mass range from a low of 89 percent for both the higher education scenarios to a high of 95 percent for the Rehabilitation Hospital scenario. The magnitude of the disparity is in part due to the fixed material mass of the os3 system, and its decreasing importance as the volume of cleaner consumed increases over the extended period of its usage. It also due to the extent to which chemical cleaning products are concentrated, maximizing the efficiency of packaging materials associated with the chemical products.

Results of the analysis are consistent with the disparity in mass noted above, with the Rehabilitation Hospital scenario reflecting the greatest benefits. Despite this, It is difficult to separate the affect of the non-water material differential from the overall impacts in this analysis. That is in part due to the water required by both systems, the mass of which dwarfs the differences of the material systems, working to obscure and offset any affects. However, because the presence of individual materials may disproportionally affect individual impact categories, the influence of non-water mass differences between the systems can be seen in the results for individual impact categories.

Use Phase Impacts

Production of Orbio os3 concentrates requires salt, tap water, and energy in the form of a small amount of electricity that is responsible for powering the generator, during its production of solution. Taken together, the impacts incurred during the use phase of the generator can be significant when compared to the system wide impacts. To demonstrate, Table 12 presents the percent of total impacts for each category attributable to the manufacture, maintenance, and use of the Orbio os3.

Table 12. Breakdown of % Impacts by Life-Cycle Stage for os3 – Community College

Impact Category	System Mfr		System Maintenance			Use of Generator		
	os3	Satellite	E-Cell	Manifold	Probe	Energy	Salt	Water
Acidification	8.2	3.3	0.3	0.1	0.0	79.5	3.2	5.5
Aq Ecotox	5.2	1.1	0.1	0.1	0.0	31.7	3.7	58.2
Eutrophication	14.3	4.4	0.6	0.2	0.0	47.4	26.7	6.4
Particulate	12.2	4.1	0.4	0.1	0.0	67.5	6.3	9.3
Global Warming	10.7	4.2	0.4	0.1	0.0	71.5	4.6	8.5
Ozone Depletion	15.5	2.0	0.2	0.1	0.0	66	6.5	9.7
Smog	12.7	4.2	0.4	0.1	0.0	68.8	4.5	8.6

As demonstrated in the above table, the consumption of energy, salt, and water can each at times make significant contributions to the overall impacts of any one category. When combined, impacts incurred during the use phase dominate the overall life-cycle impacts for the entire system, as shown in Figure 8 for the Community College scenario.

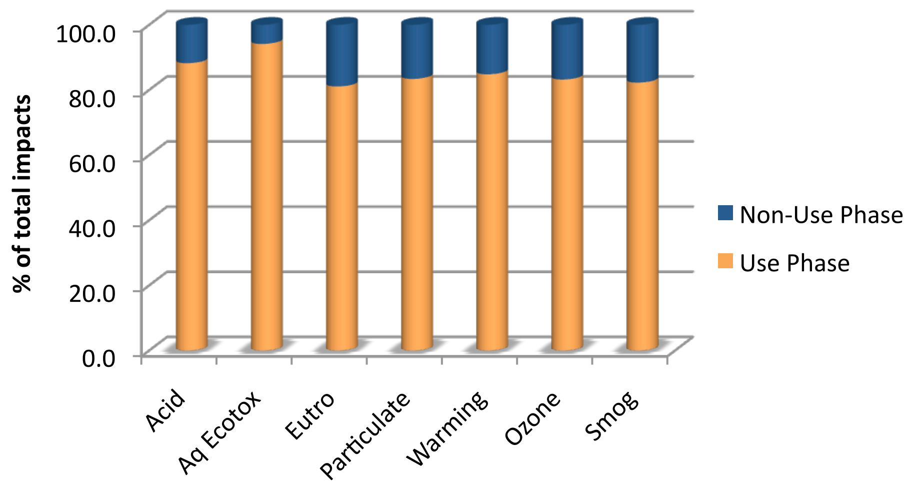

Figure 8. Use Phase Impacts as % of Total Impacts – Community College

Of the use phase impacts, energy is consistently a large, if not the largest contributor. The os3 uses 180 watts of electricity while actively producing the MultiMicro™ *Concentrate* and MultiSurface *Concentrate*, and 24 watts of electricity when idle (see Table C3 in appendix C). The overall energy consumption is therefore directly related to the overall volume of cleaning solution required for each scenario. Table 13 presents the overall amount of ready-to-use cleaning solution required for each scenario along with the total run time and total energy consumed by the Orbio® os3.

Table 13. Key os3 Operating Parameters By Scenario – 5 years

System	Life-Cycle Evaluation Scenarios		
	Rehabilitation Hospital	Community College	Four Year University
RTU Cleaning Solution (gal)			
- Cleaners	224,254	153,069	1,683,759
- Disinfectants	103,071	23,865	262,515
Operating Time – os3 (avg. hr/generator)	10,193	13,915	12,756
Idle Time – os3 (avg. hr/generator)	33,607	29,885	31,044
Total Energy Consumption* (kWh)	5,283	3,222	36,493

* Reflects total energy consumption for all os3 generators.

The energy use of the Orbio os3 is not large, roughly equivalent to the amount of energy consumed by three 60 watt light bulbs Yet, the overall effect of that energy consumption is a large contributor to the results, as shown in Table 13, above.

Energy is consistently a significant contributor in other scenarios, as well. Figure 9 depicts the percent of overall impacts in each category attributable to the energy consumption in the Rehabilitation Hospital scenario.

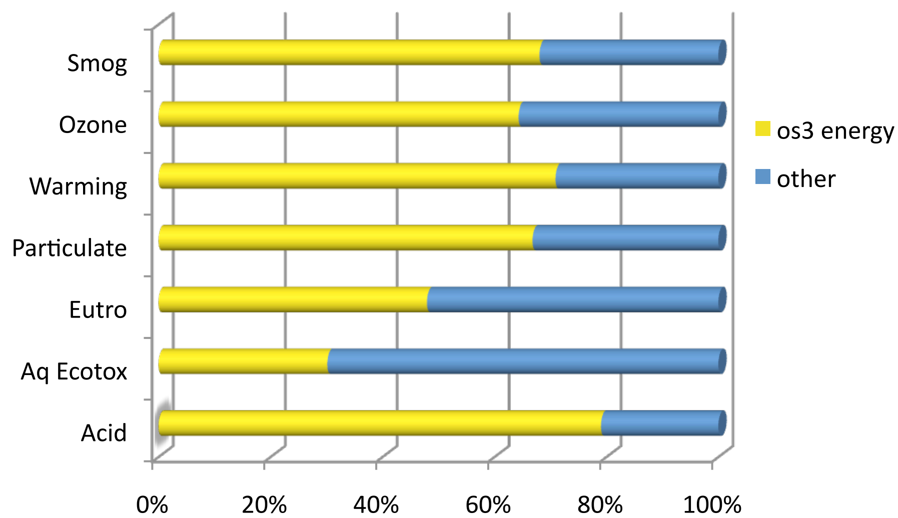

Figure 9. Use Phase Energy Consumption, as % of Total Impacts – Rehabilitation Hospital

These results are relatively consistent, given the variation of chemical volume, type, and dilution rate across the scenarios, indicating that energy is a strong driver in the overall life-cycle impacts.

Given the overall mass of materials associated with each of the alternatives (see BOMs), and that the extraction and production of these materials also consume energy, the magnitude of the effect of the energy consumed during the use stage is somewhat surprising. It would be of interest to compare the energy consumed during the use phase to the energy consumed for each alterative during the upstream manufacturing processes, especially for chemical cleaners. However, because it was necessary to use existing life-cycle data sets for chemical manufacturing, and because energy was not broken out in sufficient detail (or in some cases, at all), comparison of these values is not possible. In fact, while energy is a fundamental portion of any life-cycle inventory (LCI) dataset, we can not be certain to what extent energy was in fact included in the datasets used in this analysis, as they are poorly documented. This is an uncertainty in this life-cycle analysis.

The impacts directly correlate to the amount of os3 operating time required to produce the cleaning solution for each scenario, and thus the results relative to conventional cleaners are indirectly linked to the factors such as the extent and frequency of cleaning operations, the type of cleaner, and the concentration of the conventional chemicals requiring dilution.

The consumption of water and its influence on results is discussed later in this report.

Energy Production Data Source

Given the importance of energy to the overall outcome of this study, the selection of the life-cycle dataset used in the analysis could become relevant. In this study, a life-cycle inventory was developed to represent the energy production profile of the local utility provider for Minneapolis-USA, Xcel Energy (Xcel). This profile was created by drawing from existing life-cycle inventories representing 100 percent production of various forms of electrical power (e.g. hydroelectric) and then weighting them to mirror the production profile reported by Xcel energy for the year 2012. The Xcel Energy profile is presented in Table D1 of Appendix D.

The 2012 Xcel energy generation profile reflects a significant shift away from non-renewable sources such as hard coal (-14%) and natural gas (-18%) sources towards nuclear (+17), wind (+11), and to a lesser extent hydropower and biomass. Figure 10 depicts the % change in impacts per kWh produced as a result of using 2012 Xcel data.

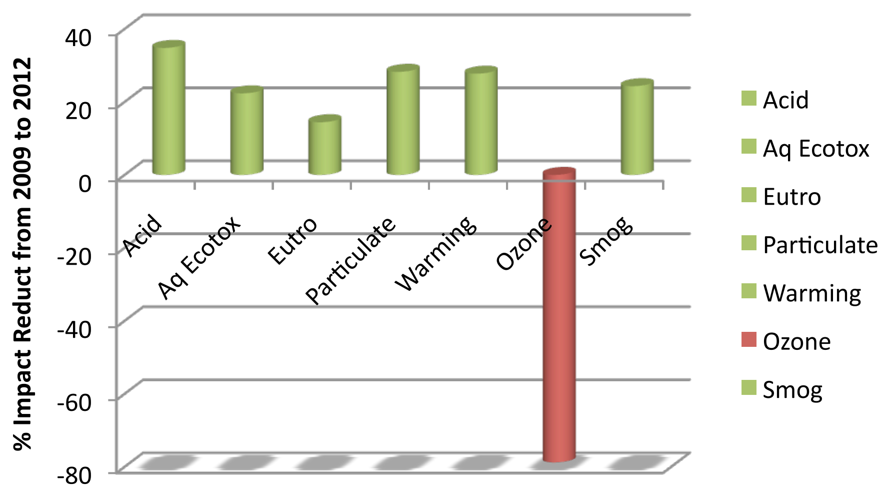

Figure 10. Percent Change in Impacts from 2009 Xcel Energy per kWh produced

To determine the sensitivity of this analysis to modifications in the source of the energy, the Rehabilitation Hospital scenario was run with both the Xcel energy inventories from 2009 and 2012, and then compared. The results for this analysis are presented in Table 14.

As shown in the table, the system is somewhat sensitive to the changes in the energy grid, with benefits ranging upward to 23 percent. However, of note is that despite the large increase in impacts in the ozone depletion category per kWh, the overall LCA results were not influenced greatly. This is most likely due to the fact that while the increase itself was significant (about 80%), the overall quantity of the release was minimal when compared to the system wide releases that factor in to ozone depletion.

Table 14. Effect of Energy LCI Source on Overall Benefits – Rehabilitation Hospital

LCA Categories		Xcel Energy - 2009	Xcel Energy - 2012	Change (%)
Acidification	(kg SO_2)	47	70	**23**
CO_2 Emissions	(kg CO_2)	70	80	**10**
Ecotoxicity	(ton TEQ eq)	48	55	**7**
Eutrophication	(kg PO4)	88	91	**3**
Ozone Depletion	(g CFCs)	97	95	**-2**
Particulate	(kg PM2.5)	67	79	**12**
Smog	(kg NOx)	75	83	**8**

The results of analyses on the remaining scenarios are similar in magnitude and effect as to those for the Rehabilitation Hospital scenario.

Water Consumption

Both the Orbio® os3 and the use of conventional cleaning products rely on significant amounts of water on-site to produce or prepare the cleaning solution at a ready-to-use concentration. Conventional daily-use chemical cleaners and disinfectants are sold in concentrated form, requiring tap water to dilute the chemicals to a concentration suitable for use in addition to the water in the formulation of the concentrate. Likewise, the os3 produces both MultiSurface *Concentrate* and MultiMicro™ *Concentrate* that requires dilution to produce ready-to-use products. The water consumption for each scenario is displayed in Figure 11, and given previously in Table 11.

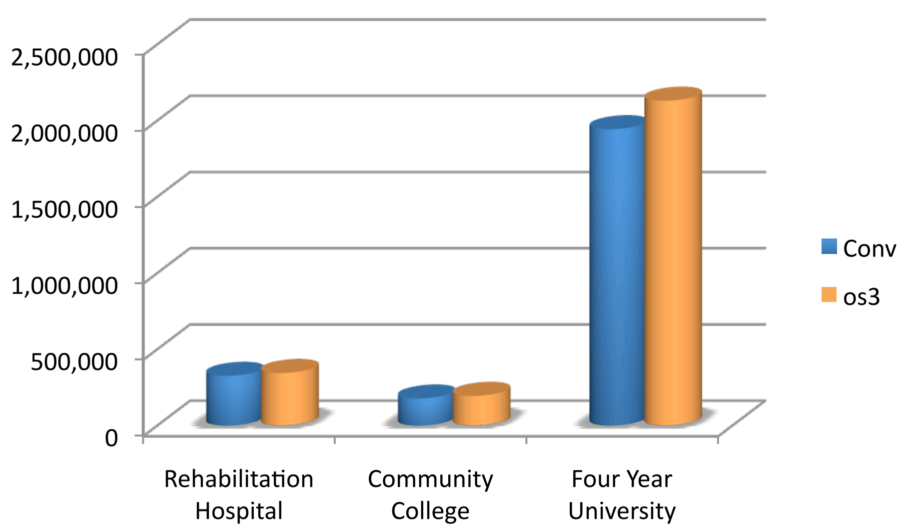

Figure 11. On-Site 5-Year Water Consumption By Scenario

As can be seen from the figure, both systems use considerable amounts of water; the os3 uses approximately 8% percent more water than used with conventional cleaners over the analysis period of 5 years. Though both systems use similar volumes of RTU cleaning solutions, a portion of the volume of the products used in the conventional cleaning chemical system is due to chemical agents, thus resulting in less water use than the os3, which derives its entire product from tap water. In addition, since the os3 generates both the MultiSurface and MultiMicro™ concentrates in a fixed proportion, a portion of the concentrate output from the os3 will at times exceed that needed to clean the building, resulting in greater than needed water use from the disposal of unused concentrate.

The disparity in water use is directly reflected in the results of this analysis. As shown in Figure 12, water consumption is a significant contributor to the aquatic ecotoxicity impact category contributing more than 60 percent of the impacts for the entire product system. These results explain the lower relative benefits of the technology in the ecotoxicity impact category as compared to those of other impact categories.

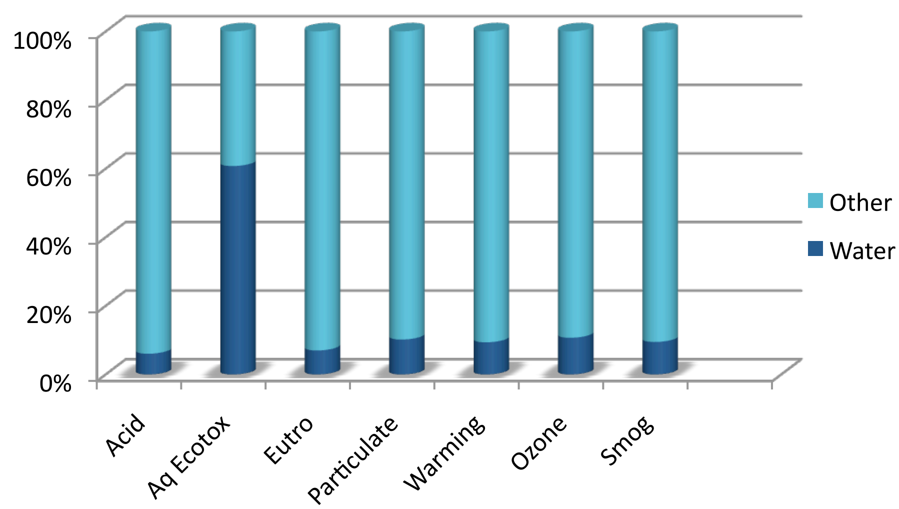

Figure 12. Percent of Life-Cycle Impacts due to Tap Water– Community College

While the additional water usage of the os3 is a negative in terms of resource consumption, the displacement of chemicals clearly results in other advantages in terms of human heath and environmental impacts, and in other life-cycle phases such as shipping.

ADDITIONAL ENVIRONMENTAL INFORMATION

Toxic Hazards

Conventional chemical cleaners are comprised of a variety of chemical compounds, some of which may pose a potential threat to human health or the environment. Cleaning chemicals are often applied during the cleaning process in a variety of methods, many of which result in inhalation exposures to chemicals of unknown toxicity, or which may leave a film of chemical residue leading to potential dermal exposures to children or other vulnerable populations. In addition, many of the chemicals applied to floor or carpet cleaning are subsequently disposed directly into the local water works where they may pose a potential hazard to aquatic ecosystems.

The cleaning solution produced by the Orbio® os3 is a low concentration of sodium hydroxide, produced through the process of electrolysis. The solution has been 3rd party tested to US EPA guidelines and proven to be nonirritating to both eyes and skin (Eurofils Study Numbers 31592 and 31593, respectively). The cleaning solution is also free of VOCs such as fragrances, asthmagens or other additives that potentially contribute to reduced indoor air quality.

The disinfecting solution produced by the os3 is a low concentration of free available chlorine in a solution of hypochlorous acid, produced through the process of electrolysis. The solution has been 3rd party tested to US EPA guidelines and proven to be nonirritating to skin and practically nonirritating to eyes (Product Safety Labs Study #37519 and 37520).

In addition, production of the chemicals through this on-site process prevents impacts associated with the upstream extraction of raw materials, and production and handling of the chemicals, greatly reducing the risk of human or environmental exposure to chemicals or their by-products elsewhere in the manufacturing chain.

LIMITATIONS AND UNCERTAINTIES

With any LCA, there are a number of limitations and uncertainties that should be considered as appropriate context for the study. One such limitation was the manner in which conventional chemical cleaners were characterized. Formulations for each of the chemical cleaning products were developed based on established knowledge and used for characterizing the conventional chemical cleaner alternative. While these formulations were representative of such cleaners, variations in chemical formulation are common within the market place. As such, these results reflect one such representation. The effect of the selection of a different chemical formulation as representative for any of the chemical cleaners on the final outcome of the study is unknown.

In addition, some of the representative formulations contained chemicals for which no life-cycle inventory data exist. In such cases, chemicals were either modeled by using combinations of data sets that together mimic the synthesis process for the missing chemical, by using available data for a chemically or structurally similar chemical, or as a last resort by determining an average inventory profile from other chemicals that serve an identical function (e.g. non-ionic surfactants). Given that any such approach involves an approximation in lieu of actual inventory data for the specific chemical, the affect of this uncertainty on the overall results of this analysis can not be specifically determined, but is unlikely to be significant given the relative impacts of any of the chemicals involved.

A portion of the Orbio® os3 roughly equivalent to 3 percent of the overall composition of the generator could not be modeled, mostly due to an inability to accurately characterize the material composition of a complex transformer assembly. The data gaps in the model prevented the full evaluation of the os3. However, an alternate analysis was performed to assess this gap by modifying the overall model to account for the additional material, assuming the material had a similar impact profile to the 97 percent characterized. Reported results reflect the adjusted values.

The performance of the os3 was conducted through the construction of individual scenarios. The chemicals use profiles for these scenarios are based upon actual data collected by Orbio from facilities of each type. The configurations for the Orbio os3 systems suitable for servicing a particular scenario are based on recommendations directly from Orbio. While the scenarios evaluated are based on actual data, variations in facilities and their associated chemical usage likely exist. These analyses are meant to represent a typical facility as described for each scenario.

Finally, secondary data sources were used in this analysis in lieu of data that could not be collected directly. Secondary data sources can vary significantly in quality and completeness and it is not often easy to determine the quality of a data set. Every effort was made by the authors to vet any secondary data sources for quality and completeness, but the authors cannot ultimately guarantee the accuracy of this data. For data sets that had a profound affect on the overall results of this study, such as those for energy and water production, alternative analyses were performed using substitute data sets to confirm the integrity of the results.

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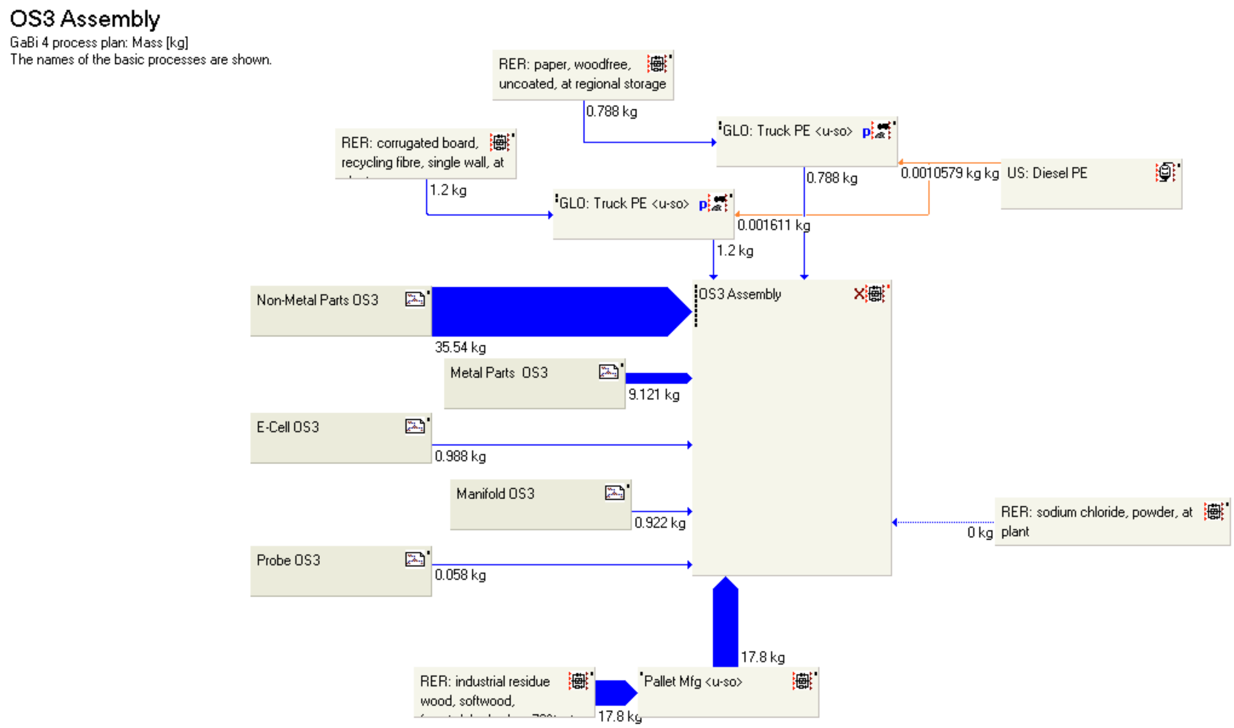
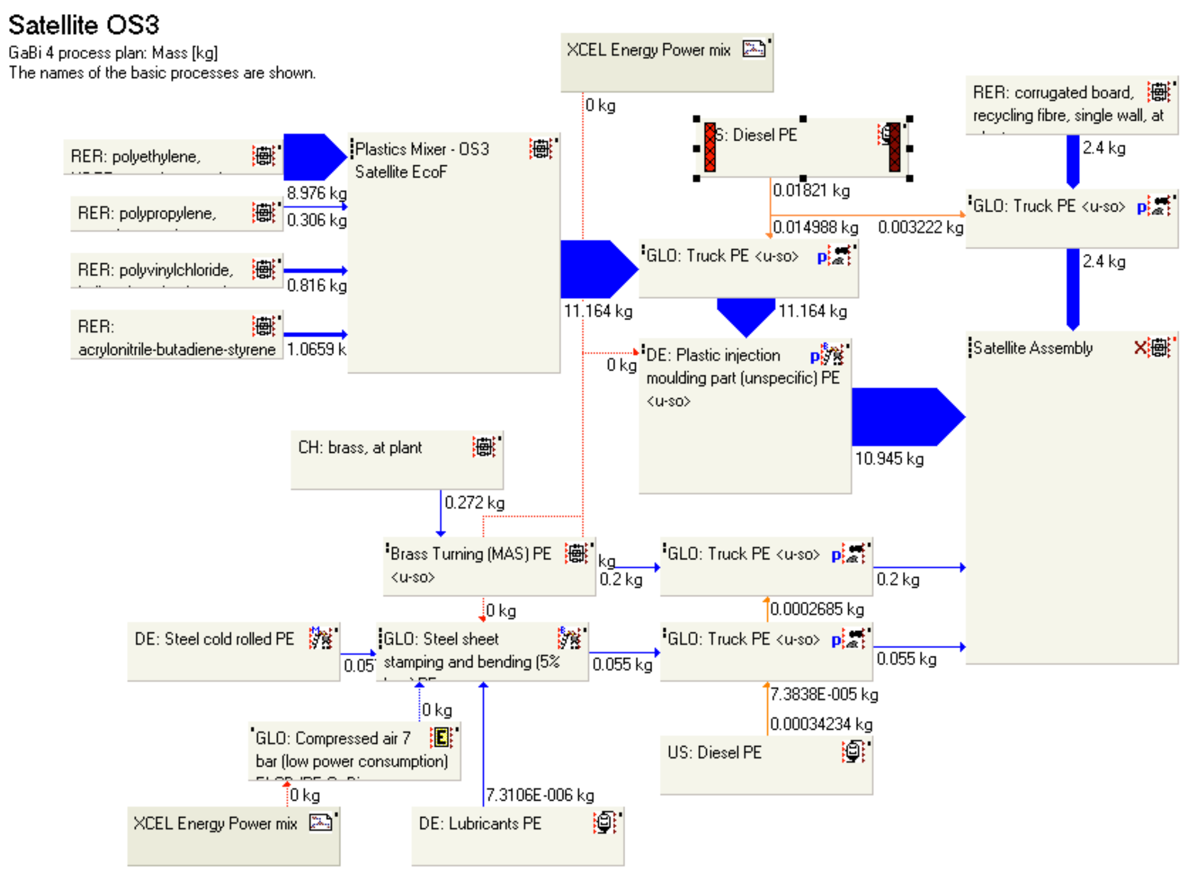
APPENDICES

Appendix A – GaBI Model Diagrams

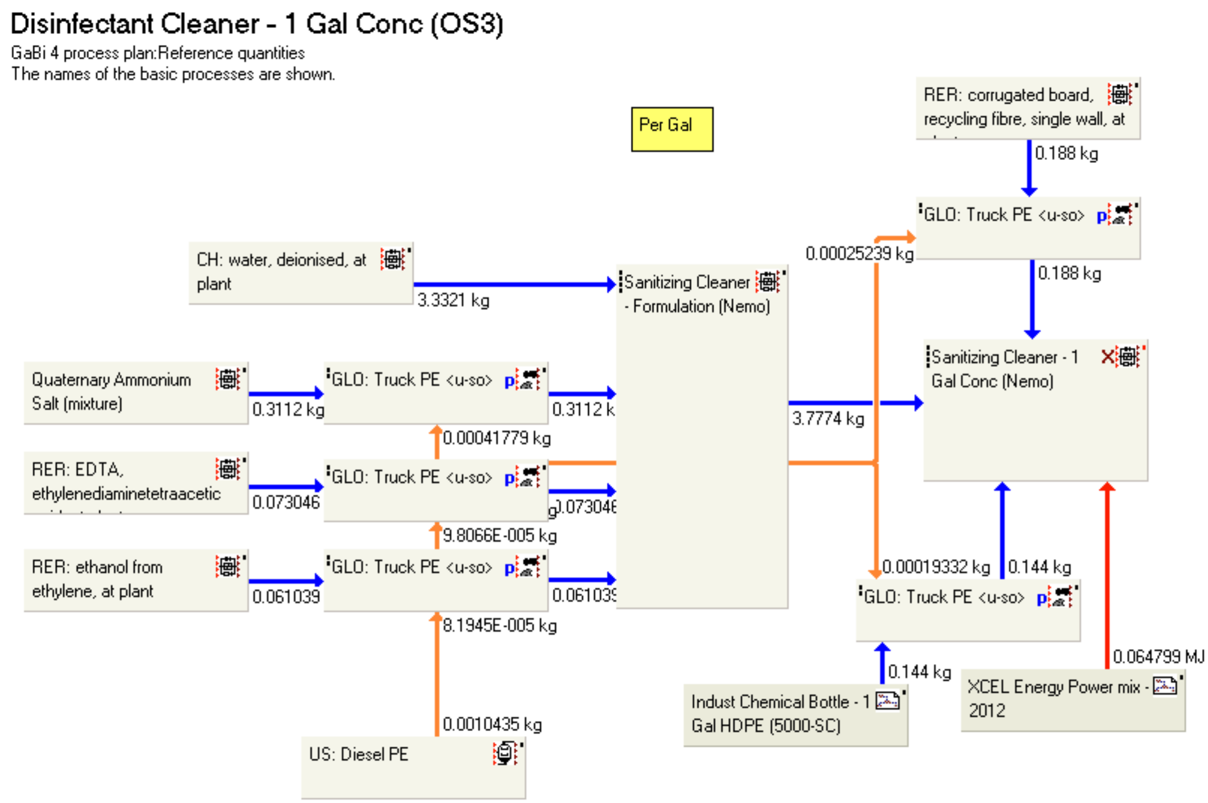
Life-cycle calculations were performed using the GaBi 6 Life-Cycle Software. GaBi model diagrams for both the Orbio® os3 and chemical-based cleaning systems are presented as samples of the life-cycle modeling performed for this analysis.

Sample os3 Model Diagram




Satellite OS3
GaBi 4 process plan: Mass [kg]
The names of the basic processes are shown.
XCEL Energy Power mix
0 kg
RER: corrugated board, recycling fibre, single wall, at
RER: polyethylene,
Plastics Mixer - OS3 Satellite EcoF
S: Diesel PE
8.976 kg
RER: polypropylene,
0.306 kg
0.01821 kg
2.4 kg
GLO: Truck PE <u-so>
0.014988 kg
0.003222 kg
RER: polyvinylchloride,
0.816 kg
GLO: Truck PE <u-so>
2.4 kg
11.164 kg
11.164 kg
RER: acrylonitrile-butadiene-styrene
1.0659 k
0 kg
DE: Plastic injection moulding part (unspecific) PE <u-so>
Satellite Assembly
CH: brass, at plant
10.945 kg
0.272 kg
Brass Turning (MAS) PE <u-so>
kg
0.2 kg
GLO: Truck PE <u-so>
0.2 kg
0 kg
0.0002685 kg
DE: Steel cold rolled PE
GLO: Steel sheet stamping and bending (5%
GLO: Truck PE <u-so>
0.05
0.055 kg
0.055 kg
0 kg
7.3838E-005 kg
0.00034234 kg
GLO: Compressed air 7 bar (low power consumption)
US: Diesel PE
0 kg
7.3106E-006 kg
XCEL Energy Power mix
DE: Lubricants PE

<u>Sample Chemical-based Cleaning Model Diagrams</u>



Appendix B – Impact Categories

Acidification, (AP): Acidification originates from the emissions of sulfur dioxide and oxides of nitrogen. These oxides react with water vapor in the atmosphere to form acids, which subsequently fall to earth in the form of precipitation, and present a hazard to fish and forests by lowering the pH of water and soil. The most significant man-made sources of acidification are combustion processes in electricity and heating production, and transport. Acidification potentials are typically presented in g SO_2 equivalents

CO_2 Emissions, (CO2): Global warming of the atmosphere occurs when carbon dioxide, methane, or other gases contributing to global warming absorb infrared radiation from sunlight, trapping it within the atmosphere. Some of the biggest human contributors to global warming are the combustion of fossil fuels like oil, coal and natural gas. This impact category includes the contributions of all such gases, even though it is expressed as CO_2 Emissions. Global warming potential are typically presented in g CO_2 equivalents.

Ecotoxicity, (AEP): Living organisms that inhabit a given ecosystem may be harmed through exposure to chemicals and other toxins released into the aquatic ecosystem. Such toxins may have a particularly harmful affect on ecosystem health including biochemistry, physiology, and the behavior and interactions of living organisms inhabiting the ecosystem. Ecotoxicity potentials are typically presented in g TEQ equivalents.

Eutrophication, (EP): Nutrients from discharged wastewater and fertilized farmland act to accelerate the growth of algae and other vegetation in the water. Oxygen deficiency then results from the degradation of organic material in the water, posing a threat to fish and other life in the aquatic ecosystem. Oxides of nitrogen from combustion processes are of significance. Eutrophication potentials are typically presented in g NO_3 equivalents.

Ozone Depletion Potential, (ODP): Stratospheric ozone is broken down as a consequence of man-made emissions of halocarbons (CFC's, HCFC's, haloes, chlorine, bromine etc.). The ozone content of the stratosphere is therefore decreasing, resulting in a thinning of ozone layer, often referred to as the ozone hole. The consequences are increased frequency of skin cancer in humans and damage to plants. Ozone depletion potentials are typically presented in g CFC equivalents.

Particulates, (P): Particulates are released as a consequence of both mobile and point source operations, usually involving combustion of materials. When inhaled, particulates directly affect humans often resulting in respiratory irritation and even prolonged chronic respiratory illness. Smaller diameter particulates, such as those smaller than 2.5 microns (PM 2.5) pose the greatest threat. Particulates are typically presented in g PM 2.5 released.

Photochemical Smog, (POCP): Photochemical smog (also referred to as ground level ozone) is formed by the reaction of volatile organic compounds and nitrogen oxides in the presence of heat and sunlight. Smog forms readily in the atmosphere, usually during hot summer weather, and contributes to respiratory illness in humans such as chronic bronchitis and emphysema. Photochemical smog formation potentials are typically presented in g ethane equivalents.

Appendix C – Key Parameters and BOMs

Life-cycle analysis was conducted on each of the alternatives for producing cleaning and disinfecting solutions and transporting them to the cleaning venue. The model for each scenario was based on a BOM calculated from data collected from actual cleaning operations for identical buildings, key operating parameters, or both. A BOM is a listing of the total materials and resources that make up that alternative. This appendix presents the key usage and operating data, as well as the BOMs for the Orbio os3 as well as for the system of conventional packaged cleaning chemicals.

Orbio os3

The Bill of Materials (BOM) in Table C1 characterizes all of the materials and resources, excluding energy, required for the Orbio® os3 to produce sufficient quantities of cleaning and disinfectant solution to perform the required maintenance and cleaning operations for each building type over the five-year period of this analysis. Energy use for each scenario is presented in the Impact Analysis portion of this document.

Table C1. Bill of Material of Orbio os3 - By Scenario (kg)

Chemical/Material	Life-Cycle Evaluation Scenarios		
	Rehabilitation Hospital	Community College	Division 1 University
Os3 generator	169	84.6	1,015
Satellite station (13.6 kg each)	40.8	40.8	326
Salt	906	619	6,800
Total Materials– Non-H20	**1,116**	**744**	**8,140**
Water Input	1,250,000	704,000	7,744,000
Total Materials	**1,251,000**	**704,700**	**7,752,000**

The Orbio os3 technology itself is comprised of a number of materials, each listed in Table C2. The total weight of the os3 generator itself is 84.6 kilograms. Each satellite is an additional 13.6 kg of materials. This total includes all of the components in the system itself, but does not include the consumables such as water or salt.

Table C2. Materials Breakdown – Orbio os3 Generator

Metals	Kg	%
Steel	0.078	0.09
Brass	0.074	0.09
Stainless Steel	6.93	8.2
Copper	0.355	0.42
Aluminum	1.69	2.0
Titanium	0.192	0.23

Plastics	Kg	%
HDPE	14	16.5
Polypropylene	5.62	6.7
ABS	1.095	1.3
EPDM	0.038	0.05
LLDPE	9.024	10.7
Polyester	1.2	1.4
Polyvinyl Chloride	4.57	5.4

Other Materials	Kg	%
PW Board	1.745	2.1
Glass	0.078	0.08
Other materials	19.8	23.3

Additional consumable materials such as salt and tap water, in addition to electrical power are required for the os3 to produce the cleaning and disinfecting solutions. The quantities are dependent on the amount of cleaning solution or disinfectant required to clean each scenario. The MultiSurface *Cleaner* produced by the os3 is a concentrate, which is diluted 10:1 to produce a ready-to-use product that is a direct replacement for the four chemical cleaners cited in this analysis. Likewise, when diluted 7.5:1, the MultiMicro™ *Concentrate* produced by the os3 becomes a disinfectant solution capable of replacing conventional disinfectants.

Table C3. Orbio os3 Operating Parameters

Parameter	Scenario Value
Concentrate Production Rate	MultiSurface – 1 Gal/hr MultiMicro – 1.4 Gal/hr
Dilution Rate	MultiSurface – 10:1 MultiMicro – 7.5:1
Energy Consumption (while generating solution)	Operation - 180 Watts Idle - 24 Watts
Salt Usage	40 lbs Salt/ 4500 gal RTU cleaning solution
Maintenance	E-cell – 36,000 gal MultiSurface Cleaner (RTU) Manifold – 120,000 gal MultiSurface Cleaner (RTU)

Conventional Cleaning Chemicals

A BOM for a conventional daily-use chemical cleaning system is presented in Table C4 for each of the three scenarios defined in this report. Values reported in the table represent the total materials and resources required to provide conventional chemical cleaning solutions in support of typical building maintenance and cleaning operations for each building type over a period of five years.

Table C4. Bill of Material of Conventional Cleaning Chemicals - By Scenario (kg)

Chemical/Material	Life-Cycle Evaluation Scenarios		
	Rehabilitation Hospital	Community College	Division 1 University
Chemicals	21,700	6,070	66,800
Packaging	859	240	2,650
Corrugate	1,120	314	3,460
Total Materials– Non-H20	**23,700**	**6,630**	**72,900**
Water (dilution)	1,169,000	637,000	7,011,000
Total Materials	**1,192,000**	**644,000**	**7,083,000**

The BOMs for each scenario were based on actual chemical usage data from cleaning operations on buildings identical to those defining each scenario. Chemical usage by product is presented in Table 8 of this report for each scenario, along with the dilution rate for each product type. All values reflect gallon of concentrate consumed per year of cleaning.

The chemical content for each of the five cleaning products was broken out by chemical ingredient and totaled by scenario in table C5. Chemical ingredients for each chemical product are identified in Tables C6-C10. When combined with the chemical usage number in Table 8, these chemical formulations formed the basis for the numbers reported.

Table C5. Breakdown of Chemical Content- By Scenario

Chemical/Material	Life-Cycle Evaluation Scenarios		
	Rehabilitation Hospital	Community College	Division 1 University
CHEMICALS (gal conc/yr)			
Propylene glycol monobutyl ether	333	46	503
Isopropyl alcohol	13	6	63
Alcohol ethoxy sulfate	9	4	48
Propylene glycol monomethyl ether	8	4	40
Ammonium hydroxide	6	3	32
Ethyl alcohol	14	4	40
Tripropylene glycol methyl ether	260	12	132
Naphthalene sodium sulfonate	130	6	66
Diethylene glycol monobutyl ether	195	9	99
Linear primary alcohol ethoxylate	130	6	66
Tetrasodium ethylenediamine	39	2	20
Alcohol Ethoxylate	424	135	1,480
SXS	136	37	412
Veresene 100, EDTA	107	19	210
Sodium metasilicate $5H_20$	86	7	80
Dimethyl octylamine oxide	13	3	33
Quat ammonium salts	65	15	165
Water (in concentrate)	3,998	1,353	14,883

Tables C6-C10 present the formulations for each of the conventional daily-use chemical cleaners and disinfectant assessed in this study. These formulations were developed using MSDS data from multiple leading brand chemical cleaners.

Table C6. Chemical Formulation- Glass Cleaner

Glass Cleaner

Diluted 12oz cleaner to 1 gallon of water	CAS #	Wt %
Propylene glycol monobutyl ether	5131-66-8	30
Isopropyl alcohol	67-63-0	8
Alcohol ethoxy sulfate	999999-83- 5	6
Propylene glycol monomethyl ether	107-98-2	5
Ammonium hydroxide	1336-21-6	4
Ethyl alcohol	64-17-5	1
Water	7732-18-5	46

Table C7. Chemical Formulation- All-Purpose Cleaner

All Purpose Cleaner

Diluted 4 oz cleaner to 1 gallon of water	CAS #	Wt %
Water	7732-18-5	68
Alcohol Ethoxylate	68439-46-3	12
Propylene glycol monobutyl ether	5131-66-8	10
SXS	1300-72-7	4
Veresene 100, EDTA	64-02-8	3
Sodium metasilicate 5H_20	6834-92-0	3

Table C8. Chemical Formulation- Daily Floor Cleaner

Daily Floor Cleaner

Diluted 1oz cleaner to 1 gallon of water	CAS #	Wt%
Water	7732-18-5	87.25
Alcohol Ethoxylate	68439-46-3	9.5
SXS	1300-72-7	2.5
Veresene 100, EDTA	64-02-8	0.75

Table C9. Chemical Formulation- Carpet Pre-Spray Cleaner

Carpet Pre-Spray

Diluted 10oz cleaner to 1 gallon of water	CAS #	Wt %
Tripropylene glycol methyl ether	25498-49-1	20
Naphthalene sodium sulfonate	26264-58-4	10
Diethylene glycol monobutyl ether	112-34-5	15
Linear primary alcohol ethoxylate	34398-01-1	10
Tetrasodium ethylenediamine	64-02-8	3
Water	7732-18-5	42

Table C10. Chemical Formulation- Disinfectant

Disinfectant

Diluted 1 oz cleaner to 1 gallon of water	CAS #	Wt %
Quat ammonium salt	7173-51-5	4.9
Quat ammonium salt	68424-85-1	3.2
Dimethyl octylamine oxide	2605-78-9	1.6
Veresene 100, EDTA	64-02-8	1.9
Ethyl alcohol	64-17-5	1.6
Water	7732-18-5	86.8

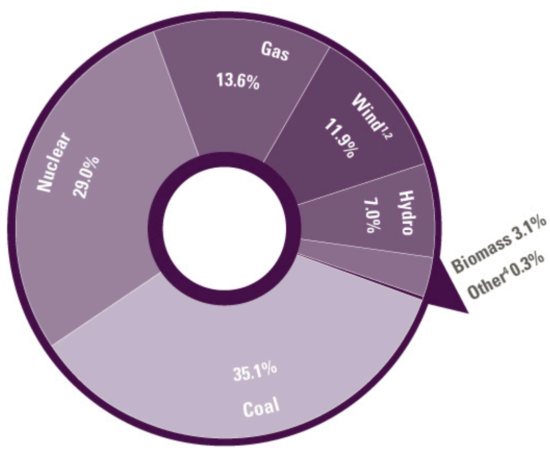
Appendix D – XCEL Energy Profile

The following table and figure describe the percent power produced by XCEL Energy in 2012, by source of the power. XCEL is the utility provider for the Minneapolis, MN area, where Orbio Technologies is currently located.

Table D1. XCEL Energy Production Fuel Profile for 2012 - Midwest

Source	% of Profile
Hard coal, power plant	35.1%
Natural gas, power plant	13.6%
Nuclear, power plant	29%
Hydropower	7%
Oil, power plant	0.3%
Biomass	3.1%
Wind	11.9%

Figure D1. XCEL Energy Production Fuel Profile for 2012 – Midwest



(https://www.xcelenergy.com/staticfiles/xe/Corporate/CRR2012/operations/generation/2012-energy-supply.html)