

Shahzeen Attari
Nan Boonyachut
David Lieberman
Neil McCarthy

Life Cycle Assessment and Green Design (12-714) Project
Life Cycle Assessment of Waterless Urinals

Abstract

This paper conducts an LCCA and LCA of a waterless urinal and compares it to a conventional water-flush urinal. A hybrid life cycle assessment was performed on 21 urinals in Baker/Porter Hall, Carnegie Mellon University over the urinal lifetime of 20 years. The results show that a waterless urinal system is generally better than a traditional urinal system from both environmental and economic perspectives.

1. Introduction

There are many reasons why some consider waterless urinals to be the wave of the future. They are reported to save an average of 40,000 gallons (151,000 liters) of fresh water per year [1]. They are also reported to save energy as water does not need to be transported to or from urinal. They also reduce the need for costly water treatment capacity. The key distinction between waterless and flush urinals is self-explanatory: flush urinals use a certain volume of water to wash urine away while waterless urinals use no flushing water. Falcon™ waterless urinals are able to deliver urine to the sewage system through two main design features: 1) A fragrant blue liquid [2], which is less dense than water and sits on top of the urine, and 2) A trap system (known as a cartridge), which allows urine to enter and leave without draining out the blue liquid.

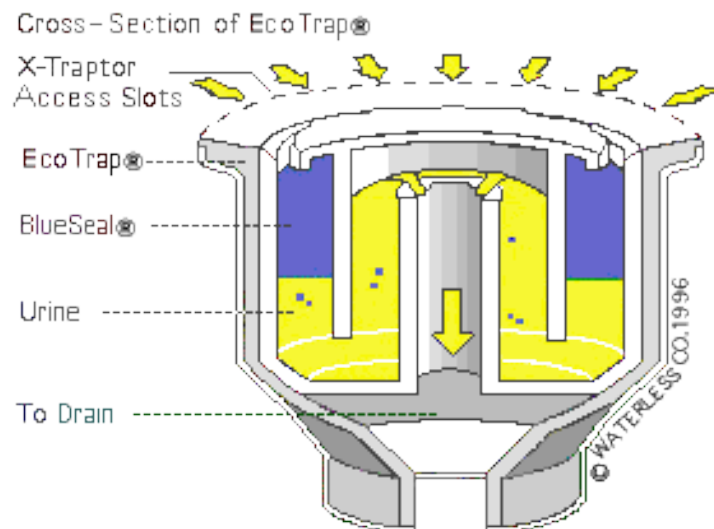


Figure 1: The cartridge in a typical water seal located at the base of a waterless urinal [1]

Flush urinals, on the other hand, use pipe fittings, a valve system, a flush, and water to transport the urine to the sewage system. Another product on the market is called UridanTM [3]. UridanTM non-water urinals operate without water or flushing. Uridan's patented built-in waste trap removes the need to replace the cartridges required by the FalconTM design. There was only limited data on the UridanTM urinals, so this alternative was modeled as a cartridge-less FalconTM urinal.

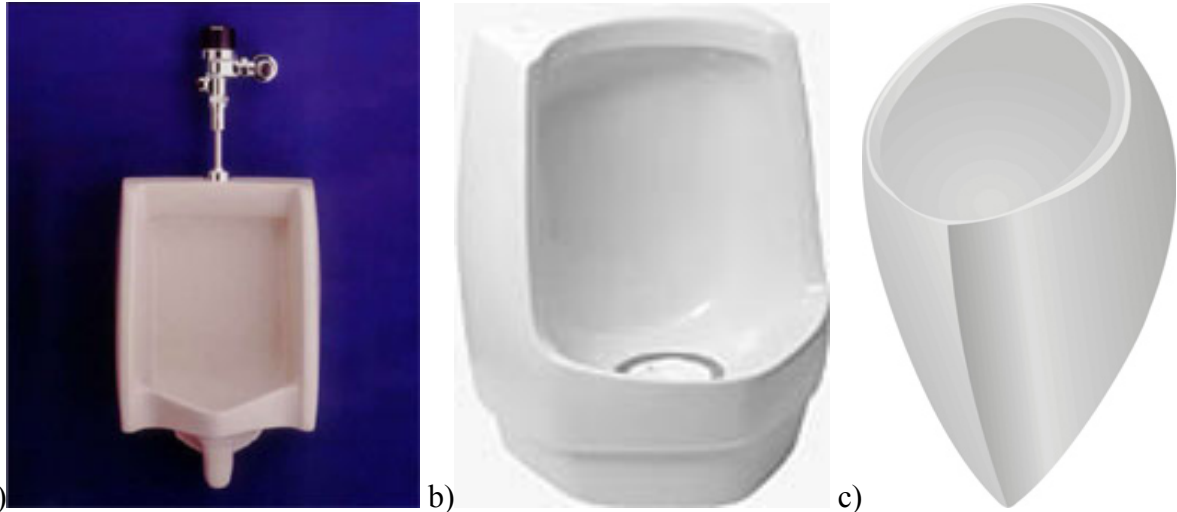


Figure 2: Typical urinals studied in this LCA, a) American Standard, b) Falcon-1000TM, and c) Uridan

Differing Features

Feature	Conventional Urinal	Falcon TM Waterless Urinal	Uridan TM
Pipe Corrosion	Diluted urine	Non-diluted urine	on-dilute urine
Pipe Mechanisms	Flush Unit	No flush unit	No flush unit
Water Use/ Flush	1gallon/flush	Waterless	Waterless
Chemical Additives	None	Blue seal	Blue seal
Cleaning	Regular wash	Regular wash Seal Trap TM Replacement	Regular wash Regular seal change
Maintenance	Replacement of gaskets, other mechanical problems	No moving parts	No moving parts
Urine Collection System	None	Seal Trap TM – Plastic	built-in trap
Installation	Flush/ pipe attachments	Drain connection only	Drain connection only
Disposal	Ceramic with metal fittings	Ceramics, plastic trap, sealant chemical	Ceramics, sealant chemical
Electricity	Use during manufacturing	Similar analysis, but for different parts	Similar analysis

Table 1: The key differences between the traditional, waterless FalconTM urinal and the Uridan system.

Similar Features

Feature	Property
Transportation	Setup, disposal, and maintenance all the same
Urinal Shape/Splash back	Similar designs for each urinal
Urinal Material	Both are ceramic
Surrounding infrastructure	Same for both
Odor	Assuming proper maintenance, urinal systems have equal odor
Raw Materials	Urinal ceramic the same (plastic Seal Trap negligible)

Table 2: The key similarities between the traditional, waterless Falcon™ urinal and the Uridan system.

A comparison will be made between the hybrid life cycle assessment (LCA) for the conventional American Standard urinal and the hybrid LCA's for the Falcon-1000™ waterless urinal and Uridan waterless urinal. In addition to the LCA, a Life Cycle Cost Analysis (LCCA) will be performed on each of these models. Specifically, analysis will be made on the current urinals in Baker/Porter Halls and the Falcon™ Waterfree [4] waterless urinals. In the analyses, the cases of both a urinal replacement and newly built urinal will be considered. The environmental and economic impacts of both waterless and standard urinals for each case will be determined. Some impacts include water usage, raw material depletion, electricity pollution, transportation emissions, and labor and maintenance costs. These impacts will be examined in three phases: production, use, and disposal for both cost and environmental impact.

The guidelines for conducting the LCA will be the ISO 14041, 14042, and 14043 standards [5]. Using these standards outline the following process: 1) Define the Goal of the LCA study, 2) Define the scope of the study, 3) Conduct a Life Cycle Inventory (LCI), 4) Conduct Life Cycle Impact Assessment (LCIA), 5) Perform interpretation, and 6) Report. The guideline for conducting the LCCA will be the National Institute of Standards and Technology's Handbook 135 [6] "Life-Cycle Costing Manual for the Federal Energy Management Program." In gathering the data, the guideline will be the EIO-LCA 1997 Annual Model.

Assumptions for both the LCCA and LCA:

General Assumptions:

- Building studied: Baker/Porter Hall
- Number of Urinals: 21 (counted)
- Lifespan of Urinal: 20 years (assumed from conversations with Facilities)
- 3 urinal uses per day per male
- 0.1 gallons-urine/flush (from UCLA 750-2500mL/person/,day)

Estimation of uses per urinal [7]:

- Porter hall houses: Department of Civil Engineering, the Department of Social and Decision Sciences and parts of the Electrical and Computer Engineering, Design and History departments.
- Baker Hall houses: College of Humanities and Social Sciences, which includes the departments of Economics, English, History, Philosophy, Psychology, Social and Decision Sciences, Statistics and Modern Languages. It also contains the Department of Engineering and Public Policy

Number of males during school year:

- 1) Department of Civil Engineering: 91
- 2) Parts of the Electrical and Computer Engineering: fraction of 604 (only one professor housed here $1/15 \times 604 = 40$)
- 3) Design and History departments: 45
- 4) College of Humanities and Social Sciences: 676
- 5) Department of Engineering and Public Policy: 27

Total # of males: 879

Assuming they use the urinal three times a day $879 \times 3 = 2637$ uses

Divide this among 21 urinals: 125 uses per day per urinal during school months.

Summer/Holiday months (doctoral students only):

- 1) Department of Civil Engineering: 20
- 2) Parts of the Electrical and Computer Engineering: fraction of 144 (only one professor housed here $1/15 \times 144 = 9$)
- 3) Design and History departments: 22
- 4) College of Humanities and Social Sciences: 87
- 5) Department of Engineering and Public Policy: 27

Total # of males: 165

Assuming they use the urinal three times a day $165 \times 3 = 495$ uses

Divide this among 21 urinals: 24 uses /day per urinal during holiday/summer months.

Of days that are working days for school: 9 months = 275

Of days that are summer/non work days for school: 3 months = 90

$(275 \times 125 + 90 \times 24) / 365 =$ averages to ~ 100 /day/urinal:

100 uses/day/urinal based on number students in Baker/ Porter

The challenge is that the 21 standard urinals in Baker/ Porter use one gallon per flush of water, and this water use is costly. The objective is to determine whether or not replacing the standard urinal with a urinal that consumes less water would be cost-effective. These analyses will be performed for both a new bathroom and an existing bathroom over the urinal lifetime of 20 years.

Project Description

The type of building considered is an academic building used for classrooms, offices, laboratories, and bathrooms. The bathrooms are mainly considered here. The climate (which affects the condition of the bathroom pipes) is temperate. The urinal must

meet the criteria of hygienically delivering urine to the sewage system. Desirable features include limited splash back and odor.

Type of Decision to Be Made

The type of decision being made is an “optimal system” decision. The choice is between a standard urinal and a waterless urinal on the basis of cost-effectiveness.

Constraints

Urinals require only water and the infrastructure for water and sewage to function. Both of these features are readily available in Baker/ Porter, so there are no foreseeable constraints for urinals in Baker/ Porter.

First Alternative: Keep or Install Conventional Urinals

The as-is scenario is the first possible alternative. The current urinals in Baker/ Porter are American Standard, one gallon per flush. The rationale for considering this alternative is that it might be cheaper than installing a waterless urinal. Non-monetary considerations include environmental concerns.

Second Alternative: Replace Existing Urinals with Falcon™ Waterless Urinals

Since the urinals in Baker/ Porter are already considered to be water-efficient, replacing the existing urinal with a urinal that uses less water will not be considered. So, analysis will be performed on the life cycle cost of removing an existing urinal and replacing it with a waterless urinal. Rather than analyze all the different brands of waterless urinals, the brand with the most readily-available data and the most accessible test sites will be considered. Since there is a Falcon™ urinal nearby, and since there is more data available on Falcon™ than most other waterless varieties, Falcon™ waterless urinals became the model of analysis. This alternative is being considered because, mainly due to water consumption, it might save money over the existing urinal. Non-monetary considerations here also include environmental factors.

Third Alternative: Install Waterless Urinals to New Bathrooms

This alternative proposes installing a new, Falcon™ waterless urinal into a new bathroom. This alternative is similar to the second alternative, only for a new bathroom instead of an existing bathroom. This alternative is considered because it might be cheaper than installing a standard urinal.

Fourth Alternative: Uridan Waterless Urinals, Installed New

The fourth alternative is the Uridan waterless urinal. This alternative is analogous to the Falcon™ waterless urinal, except it does not have the Seal Trap. So, to this alternative was modeled as a Falcon™ urinal without Seal Trap factors. Due to data constraints, an Uridan Replacement scenario was not considered.

Common Assumptions and Parameters

Base Date, Service Date, and Planning/ Construction Period

The base date will be assumed to be $t=0$ at the time of installation of the urinal. The service date will be the same as the base date, $t=0$. There is no delay between the

base date and the service date, so there is no Planning Construction period. The service period will coincide with the study period. This time span is the life of one urinal, 20 years.

Length of Study Period and Service Period/ Discount Rate

The length of the study period will be the lifetime of one urinal, or 20 years, which will coincide with the service period. It is assumed that all the costs of the different characteristics of the urinals will grow at the same rate as the rate of inflation. Thus, a discount rate will not be used for this project.

Uncertainty of Input Data

Data Sources table in appendix A shows the sources of the data used. The certainty of the data is subject to the reliability of these sources. The most notable data uncertainty lies in the estimations made regarding the cost of maintenance. Early approximations were based on unreliable conversations with facilities plumbing personnel. Maintenance work orders, made available after the conclusion of the study, show one year's maintenance costs for Porter urinals to be \$900 [8]. If costs for the 8 urinals of Porter hall are extrapolated to all 21 urinals, the costs related to work orders is only \$300/year less than our original estimate. The error is not unreasonable, so our overall results are still valid.

Effects for Which Dollar Costs or Benefits Can Not Be Estimated

There are a few factors that could not be quantified economically:

- 1) Splash back: Upon visiting with employees of CMU's Facilities, Maintenance, and Services building, it was learned that they decided not to convert from the conventional to the waterless system because of and splash back issues. However, at Claire's hospital, where employees have installed a number of FalconTM urinals, they said they did not have trouble with splash back. Different urinal models online showed that the parabolic shape minimizes splash back, but all of the designs encountered employed a parabolic-like shape. So, it was assumed that all models have the same amount of splash back.
- 2) Odor: A few people had concerns about the odor of the waterless system (fearing that the odor may be more than that of the conventional system). It is next to impossible to quantify this. This was because St. Claire's employees (who claimed there were no odor problems) provided different testimonials than the Facilities testers, who said that there was an odor problem with the waterless system. So, it was assumed that, if the waterless urinals are cleaned according to their guidelines, the odor factor can be assumed to be negligible.
- 3) Cleaning: The Uridan system involves more intimate handling of the urinal than the waterless. This may be a bit unpleasant for the people who clean the urinals but was hard to quantify so it was assumed that there was equal labor and equal pay for the cleaners in each system.
- 4) Desire to hear the gush of the flush: After speaking to a few people who have used the waterless system, it was discovered that many of them wanted to feel the

satisfaction of flushing the urinal at the end, but there was no way to quantify this. It was assumed that people would use the urinals regardless, thus there would be no cost difference between the two in this category.

Goal of the Study

The intended application of this study is to determine the cradle to grave environmental and economics effects of urinals when installed in Baker/ Porter hall. All four scenarios will be studied to determine the best case scenario. The intended audience is CMU Facilities and Maintenance, as they would ultimately be responsible for deciding whether or not to replace or install the urinals.

Scope of the Study

System Function/ Functional unit/ System Description

The function of the system is to hygienically deliver urine to the sewage system. The functional unit is the amount of urine discharged into Baker/Porter urinals each day. The system encompasses all the urinals in Baker/Porter and the attached piping over the 20 year life span of a urinal.

System Boundaries

The unit processes included in the LCA are:

- Production, use, and disposal/recycling of all urinal components and sealant (waterless urinals).
- The lifetime environmental impact of water used for flushing standard urinals.
- The environmental impact of extraction, production, use, and disposal/recycling of the plastic components used in the waterless urinal, including a factor for replacing the plastic traps periodically.

The main environmental impacts that will be considered are the inputs and outputs to make the plastic urine traps for the waterless system and the water usage for the standard urinal.

Other flows taken into consideration include:

- Inputs and outputs in the manufacturing of each type of urinal
- Transportation of the maintenance workers required to keep up the waterless urinals. Regular maintenance transportation and urinal delivery transportation shall be held equal across the different urinal scenarios.
- The heat and electricity needed to produce each urinal shall be considered.
- A factor shall be included for the replacement of the plastic traps; all other maintenance is equal between the three urinal scenarios.
- It will be assumed that all parts of all urinals will be disposed at the end of life.
- Production shall assemble the parts created, package these products and ship them to the bathrooms, and install them in the bathrooms

- From the time of installation, use shall include all the time that the urinal spends in the bathroom, where it is transformed from a new urinal to a used urinal.
- The used urinal enters into the disposal phase where it becomes waste.

Allocation Procedures

Impacts were allocated according to direct inputs and outputs of each urinal system. The product flows through the system were further allocated according to results from EIO-LCA. The impacts from the in-use phase were allocated to either direct water usage or to the secondary impacts related to materials and consumables. The major components of the end-of-life phase are all not readily recyclable, so impacts are all allocated to the effects of landfill disposal.

Impact Categories and Impact Model

The impact categories will include water usage, electricity emissions, and loss of raw materials. Loss of habitat will not be considered since urinals are sent to a landfill at end-of-life (and not dumped in a river or lake, etc).

Limitations

In data-gathering, limitations were subject to the data given by FalconTM, Uridan, other studies related to waterless urinals, and data given by CMU facilities and the St. Claire hospital. (They each have a FalconTM waterless urinal on site).

Data Quality Requirements

The data shall calculate:

- Time factors for reinstalling plastic traps and time factors for water usage. All other time factors are essentially equal.
- Both urinals have to be delivered from a distance, so geographical factors shall be held equal.
- The technology of the odor sealant shall be considered. All other components do not involve any technological innovations.
- Data for water usage and plastic trap impacts shall be most precise. Other calculations will be made, but not to the same detail.
- The primary sources for data will be FalconTM waterless systems and CMU Facilities.

Peer Review

This LCA shall be reviewed internally by a faculty member at CMU who is an expert in the LCA field. This document will also be reviewed by Facilities at CMU.

Life Cycle Inventory

Each of the urinal systems studied are divided into 3 major phases: production, in-use and end of life. In order to produce the products needed for proper use of the conventional or waterless urinal systems, the ceramics, metals, plastics, and chemicals industries each require significant amounts of input. Studying the production phase involved estimating these inputs using the EIOLCA model. The in-use phase requires only the water needs of the urinal and regular maintenance costs. The end-of-life phase

includes the landfill disposal of all significant parts, which include urinals themselves and replacement cartridges. Water use during the in-use phase will be determined by process-based analysis, whereas other extended impacts beyond the production and end of life phases will be estimated using the EIO-LCA model.

The following process diagrams, Figures 3-6, show the proposed materials flow for each of the studied scenarios. The conventional urinal scenario highlights the increased use of metal products as well as the significantly higher use of water. Figures 4 and 5 shows the reduced amounts of water flow with the addition of plastic cartridges. Figure 4 additionally considers the initial costs of having previously installed the conventional equipment. Figure 6 shows that the materials flows necessary for the Uridan brand urinal avoid the water usage as well as the need for cartridge replacement.

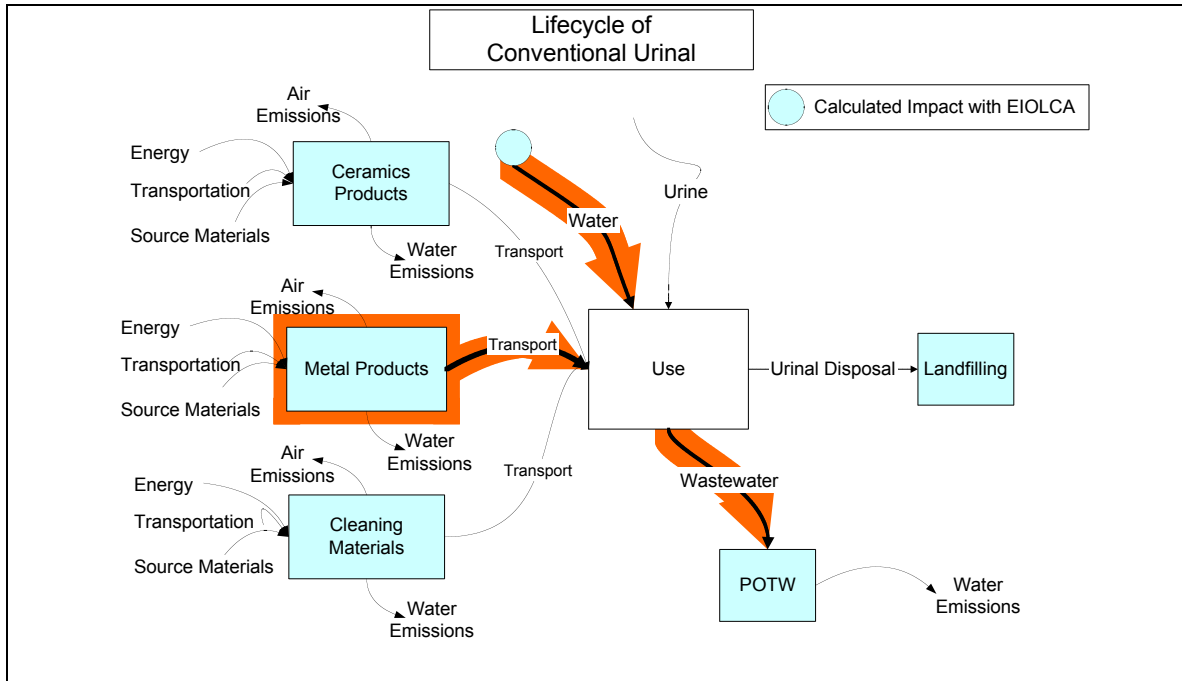


Figure 3: Lifecycle of Conventional Urinal

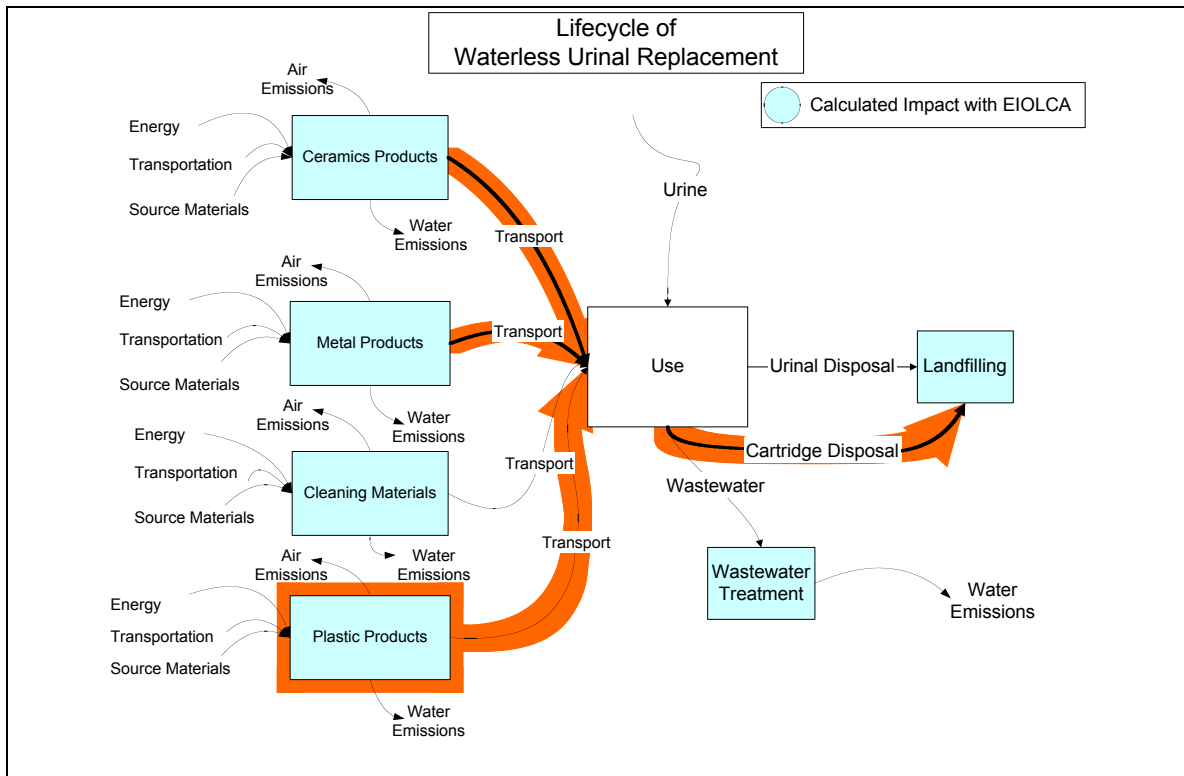


Figure 4: Lifecycle of Waterless Urinal Replacement

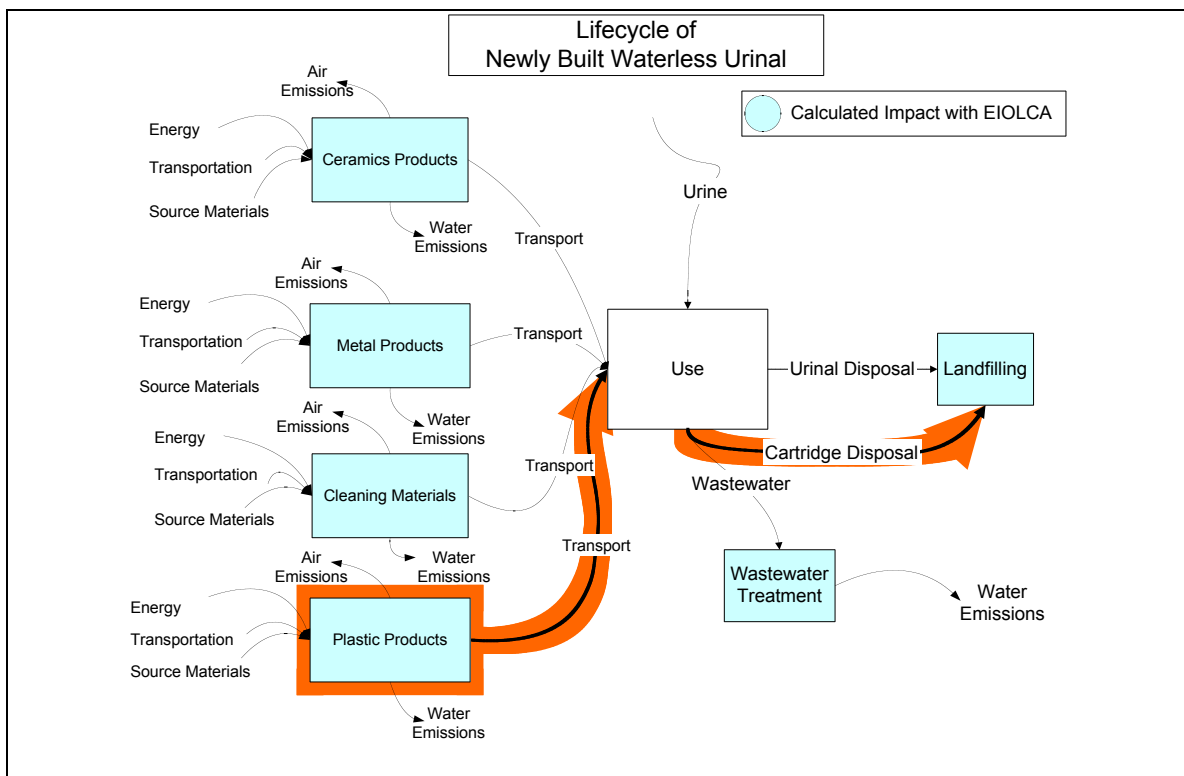


Figure 5: Lifecycle of Newly Built Waterless Urinal

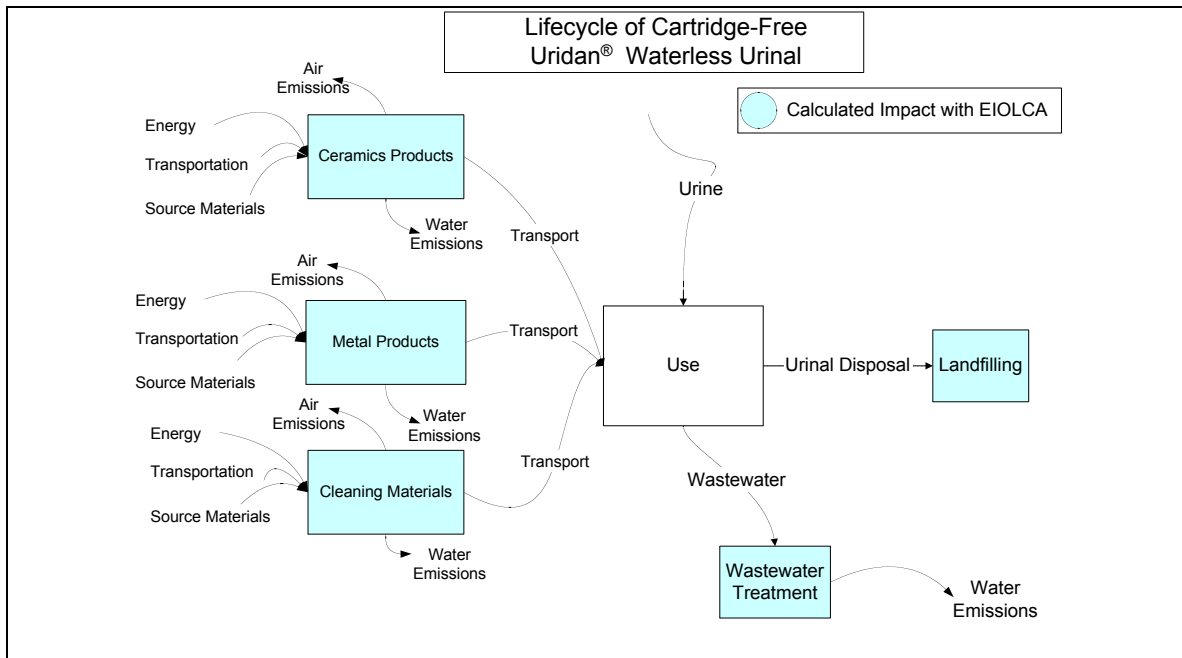


Figure 6: Lifecycle of Cartridge-Free Uridan Waterless Urinal

Estimate Cost and Times of Occurrence for Each Alternative

In order to make the necessary cost calculations, a variety of information was collected regarding each of the flows described in the previous section. This data, along with corresponding sources and levels of uncertainty, is tabulated in Appendix X. This information was then used to calculate the life cycle costs associated with the material flows of each scenario. Appendix tables Q-T detail the calculations used to produce the results found in Table 3.

The results of production phase show some distinct differences between the scenarios. Waterless replacement is understandably more costly than conventional urinal, as the scenario involves building on top of existing equipment. The new waterless scenarios are both more cost effective in the production phase due to the lack of costly flush mechanisms and half of the piping infrastructure.

The in-use differences between scenarios, also evident from this cost comparison, become more pronounced with time. The difference in water usage dominates all other aspects of the cost comparison. The labor costs of gasket maintenance, though a potential source of uncertainty, only contribute to the added cost of conventional urinals. The cost of using Falcon™ replaceable cartridges is a significant one that can be minimized by shifting to use of the Uridan urinals. All of these annual costs will add up to significant differences by the end of the products' lifetimes, as is clearly shown in Figure 7.

Annual costs are estimated as follows:

	Conventional	Waterless- Replacement	Waterless New	Uridan - No Cartridge
Production				
Ceramic Bowl	8064	8400	8400	8295
Metal Pipes (wastewater)	355	355	355	355
Pipe connection (wastewater)	180	180	180	180
Metal Pipes (water line)	355	355		
Pipe connection (waterline)	180	180		
Flush Mechanism	3150	3150		
Disposed of Replaced Bowl		44		
Use				
Potable Water usage	5542			
Wastewater production	1231	112	112	112
Gasket maintenance parts	504			
Gasket maintenance labor	2205			
Brush	8	8	8	8
Regular cleaning	2520	2520	2520	2520
Cartridge (seal included)		3832.5	3832.5	
Cartridge disposal		3.6	3.6	
Sealant fluid				479
End of Life				
Disposal	44.4	44.4	44.4	44.4

Table 3: Yearly cost breakdown for each alternative.

The “production” category shows all the initial costs at time t=0. The “use” category shows all the future annual costs over the 20-year life of the project.

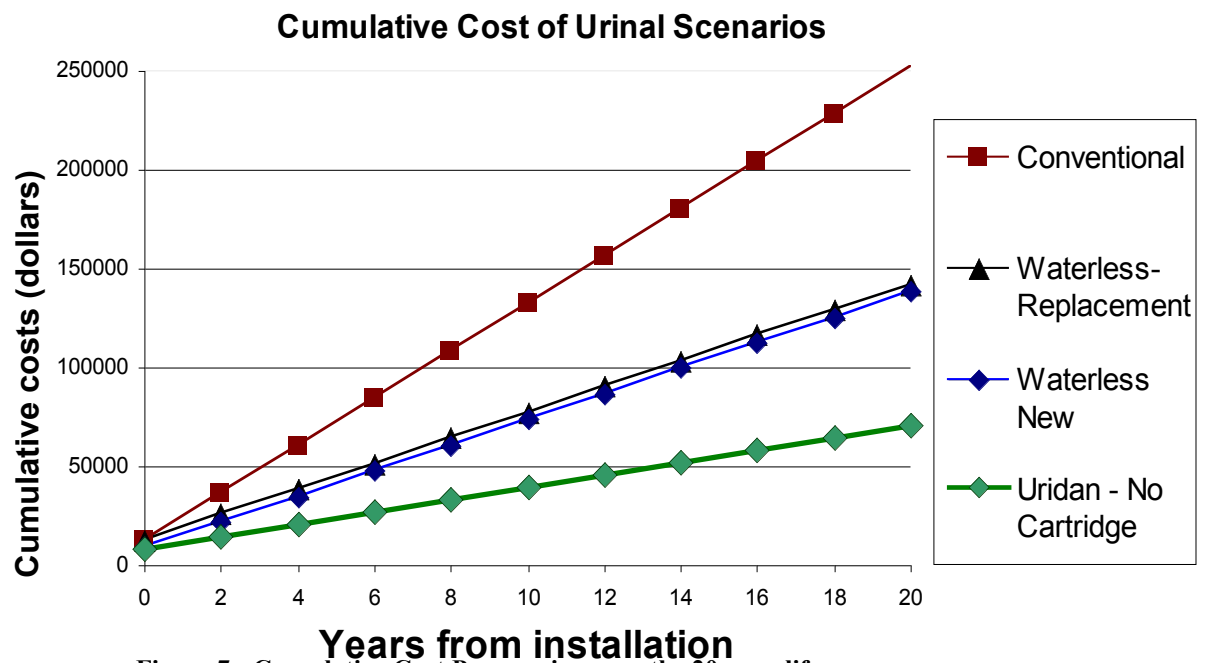


Figure 7: Cumulative Cost Progression over the 20-year lifespan

2. Urinal LCA: As-Is, Waterless Replacement, Waterless New, and Uridan Cartridge-free New

Life Cycle Impact Assessment

Life cycle impact assessment was carried out with hybrid life cycle analysis. Process models for each of the four urinal alternatives can be categorized in the following sectors:

Component	Sector
Urinal (initial)	360600: Vitreous china plumbing fixtures
Falcon™ Urinal (waterless)	360600: Vitreous china plumbing fixtures
Uridan Urinal (waterless)	360600: Vitreous china plumbing fixtures
Flush valve (initial)	420800: Pipe, valves, and pipe fittings
Fresh water pipe (initial)	420800: Pipe, valves, and pipe fittings
Disposal pipe (initial)	420800: Pipe, valves, and pipe fittings
Fitting (initial)	420800: Pipe, valves, and pipe fittings
Brush	320400: Miscellaneous plastics products, n.e.c.
Cleaning chemical	290201: Soap and other detergents
SealTrap™ Cartridge	320400: Miscellaneous plastics products, n.e.c.
Sealant Fluid	290201: Soap and other detergents
Maintenance	120300: Other repair and maintenance construct
End of life	680302: Sanitary services, steam supply, and irrigation systems

Table 4: EIOLCA sectors for urinal components

Environmental impacts are obtained from EIO-LCA 1997 annual model. The total life cycle impacts are listed in table 5. A chart representing these impacts is shown in figure 8.

	Conventional	Replacement	Waterless	Uridan
Effects	Total	Total	Total	Total
Economic Purchased [\$ million]	0.44	0.20	0.18	0.14
Electricity Used [Mkw-hr]	0.07	0.05	0.05	0.04
Energy Used [TJ]	1.84	1.15	1.02	0.83
Conventional Pollutant [metric tons]	1.59	0.80	0.70	0.56
OSHA Safety [fatalities]	0.00	0.00	0.00	0.00
GHG [100 metric tons CO2 eq.]	1.42	0.79	0.70	0.56
Fertilizers Used [\$ million]	0.00	0.00	0.00	0.00

Fuels Used [Tera joules]	1.76	1.09	0.97	0.79
Ores Used [100 metric tons]	0.22	0.16	0.12	0.10
Hazardous Waste [RCRA, 100 metric tons]	0.12	0.13	0.13	0.10
External Cost Incurred [median, \$ million]	0.01	0.00	0.00	0.00
Toxic Released [metric tons]	0.12	0.12	0.10	0.07
Weight Toxic [metric tons]	0.73	0.46	0.17	0.13
Water Used [million gallons]	1.61	0.72	0.69	0.56

Table 5: The total environmental impact for all cases

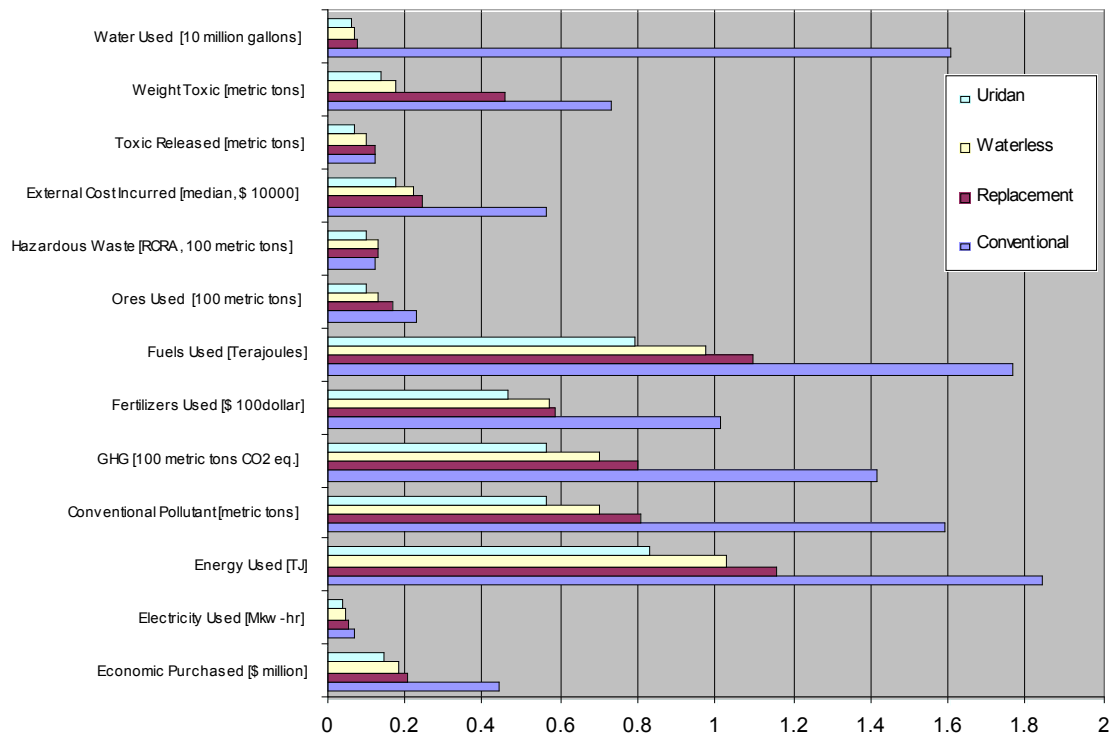


Figure 8: Total Life Cycle Environmental Impact Chart showing environmental impact of all four alternatives for the categories obtained from EIO-LCA.

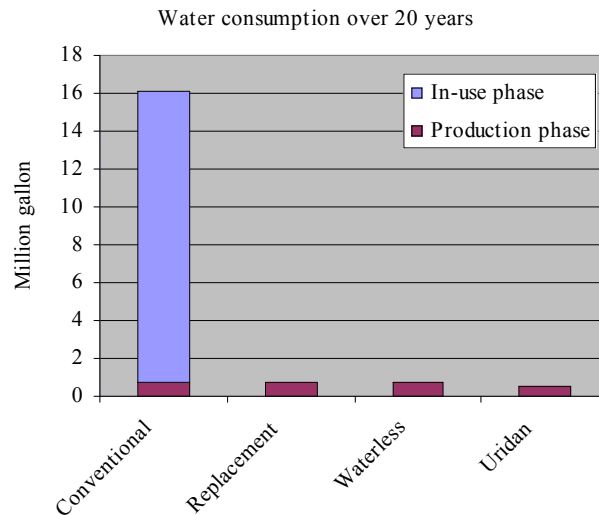


Figure 9: Total water consumption over 20 years

In order to compare the whole life cycle of water impact, the direct water usage from actual flushing in the conventional urinal and the water required for cleaning the waterless urinal are included. The total amount of water usage for the whole life cycle of all alternatives is shown in Figure 9. The water usage from the actual flush alone is substantial. Over its 20-year life span, the conventional urinal requires approximately 15 million gallons of water to function. The amount of water required to clean the waterless urinals is negligible.

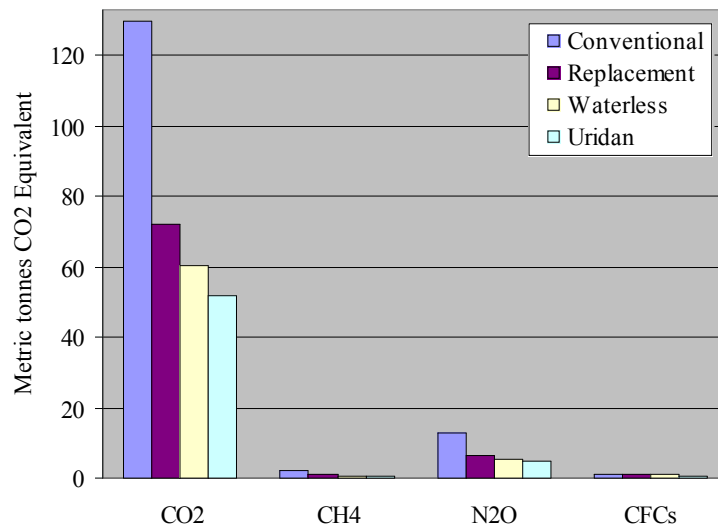


Figure 10: Greenhouse gas emissions over the urinal lifetime

For all waterless urinals, the Greenhouse gas emissions and conventional pollutants stem from only the production phase. Most of the greenhouse gas emissions and conventional pollutants come from the production of the plastic cartridges (in Falcon™)

and sealant fluid, which is a consumable product. In addition to regular maintenance, the conventional urinal's in-use phase requires periodic replacement of the flush valve gasket.

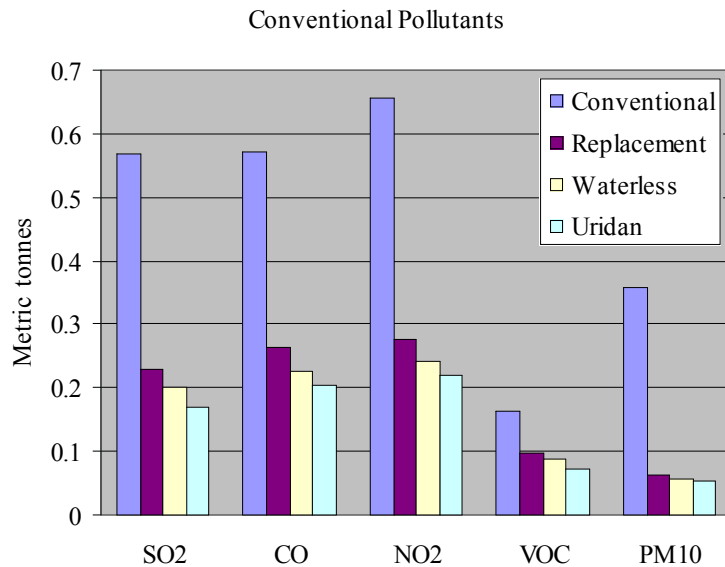


Figure 11: Conventional pollutants, Lifetime

Additionally, conventional urinals also need water and sewage supply to support their systems. Because of these factors, the conventional urinal shows more greenhouse gas emissions and conventional pollutants. Electricity generation and transportation factors cause most of the greenhouse gases and conventional pollutants.

Interpretation

To tabulate a result for all the data, first, an equally-weighted rank factor was assigned to each alternative in each category from Table 5. These ratings were calculated by assigning a “1” to the alternative with the most impact (shown in bold). The other three ranks were then calculated by determining the ratio of their respective impacts in relation to the alternative rated “1”. The totals at the bottom of the chart indicate the total impact for each category using an equal-weight scheme. The alternative with the highest number has the most environmental impact, while the alternative with the lowest number has the least environmental impact. Here are the results of that ranking:

Effects	Rank Factor			
	Conventional	Replacement	Waterless New	Uridan
Economic Purchased [\$ million]	1.00	0.45	0.41	0.32
Electricity Used [Mkw-hr]	1.00	0.71	0.71	0.57
Energy Used [TJ]	1.00	0.63	0.55	0.45

Conventional Pollutant [metric tons]	1.00	0.50	0.44	0.35
OSHA Safety [fatalities]	0.00	0.00	0.00	0.00
GHG [100 metric tons CO2 eq.]	1.00	0.56	0.49	0.39
Fertilizers Used [\$ million]	0.00	0.00	0.00	0.00
Fuels Used [Tera joules]	1.00	0.62	0.55	0.45
Ores Used [100 metric tons]	1.00	0.73	0.55	0.45
Hazardous Waste [RCRA, 100 metric tons]	0.92	1.00	1.00	0.77
External Cost Incurred [median, \$ million]	1.00	0.00	0.00	0.00
Toxic Released [metric tons]	1.00	1.00	0.83	0.58
Weight Toxic [metric tons]	1.00	0.63	0.23	0.18
Water Used [million gallons]	1.00	0.45	0.43	0.35
Total Cost (\$1000)	1.00	0.56	0.55	0.28
Total	<u>12.92</u>	<u>7.84</u>	<u>6.75</u>	<u>5.15</u>

Table 6: Environmental Impacts Weighted Equally

Next, for weighting purposes, it was decided to aggregate the results into four broad sectors: economic, energy, pollutants and water. Here are those grouping, which include tallies of group weighting factors (note that these calculations included “total cost” from the LCCA into the economic category):

<u>Energy</u>	Rank Factor			
	Conventional	Replace	Waterless	Uridan
Fuels Used [Tera joules]	1.00	0.62	0.55	0.45
Energy Used [TJ]	1.00	0.63	0.55	0.45
Electricity Used [Mkw-hr]	1.00	0.71	0.71	0.57
Conventional Pollutant [metric tons]	1.00	0.50	0.44	0.35
GHG [100 metric tons CO2 eq.]	1.00	0.56	0.49	0.39
Ores Used [100 metric tons]	1.00	0.73	0.55	0.45
Total	6.00	3.75	3.30	2.67
<u>Pollutants</u>				
Toxic Released [metric tons]	1.00	1.00	0.83	0.58
Weight Toxic [metric	1.00	0.63	0.23	0.18

tons]				
Hazardous Waste [RCRA, 100 metric tons]	0.92	1.00	1.00	0.77
Total	2.92	2.63	2.07	1.53

Economic

Economic Purchased [\$ million]	1.00	0.45	0.41	0.32
External Cost Incurred [median, \$ million]	1.00	0.00	0.00	0.00
Total Cost (\$1000)	1.00	0.56	0.55	0.28
Total	3.00	1.02	0.96	0.60

Water

Water Used [million gallons]	1.00	0.45	0.43	0.35
---	------	------	------	------

Table 7: Impact factors aggregated into sectors

After grouping like categories together, two separate weighting schemes were employed to analyze the data. First, an “Economic” model was used. A total scale of “10” was chosen, giving the Economic category a “5,” water a “3,” (water costs are important to economists), and pollutants and energy a “1” (environmental effects are externalities to economists): Here are the results:

Aggregated sector	Economic Weighting Scheme								
	Impact Category Rank Factor				Weight	Weighted Impact Rank Factor			
	Conv.	Replace	W'less	Uridan		Conv	Replace	W'less	Uridan
Energy Total	6.00	3.75	3.30	2.67	1.00	6.00	3.75	3.30	2.67
Pollutants Total	2.92	2.63	2.07	1.53	1.00	2.92	2.63	2.07	1.53
Economic Total	3.00	1.45	1.34	0.91	5.00	15.00	7.25	6.72	4.53
Water Total	0.43	0.45	0.43	0.35	3.00	1.30	1.34	1.29	1.04
Total						25.22	14.97	13.37	9.78

Table 8: Economic weighting scheme.

Next, an environmental weighting scheme was employed. Environmental categories were assigned each a “3”, with the economic category a “1.” Here are the results:

Aggregated sector	Environmental Weighting Scheme								
	Impact Category Rank Factor				Weight	Weighted Impact Rank Factor			
	Conv.	Replace	W'less	Uridan		Conv	Replace	W'less	Uridan
Energy Total	5.00	3.05	2.71	2.18	3.00	15.00	9.16	8.14	6.55
Pollutants Total	2.93	2.60	2.02	1.50	3.00	8.78	7.79	6.07	4.50
Economic Total	3.00	1.45	1.35	0.91	1.00	3.00	1.45	1.35	0.91

Water Total	1.00	0.05	0.04	0.03	3.00	3.00	0.14	0.13	0.10
Total						29.78	18.54	15.69	12.06

Table 9: Environmental weighting scheme.

Conclusion

A life cycle cost assessment and life cycle assessment were performed on a standard urinal, a FalconTM waterless urinal replacement, a FalconTM waterless urinal installed into a new bathroom, and a Uridan waterless in a new bathroom. In the assessments, the 21 urinals in the bathrooms of Baker/ Porter hall were considered. The urinals were analyzed over their lifetime of 20 years.

Due mainly to water consumption costs, the conventional urinals cost the most of the four alternatives over the 20-year life. The FalconTM replacement was second-highest. Separated by only a small initial cost, the new FalconTM installation was the third costly. Even less costly than all those was the Uridan waterless urinal. This is why, from a cost perspective, Uridan waterless urinal is the urinal of choice

The rankings for the LCA results were unanimous over all three models (equal-weighting, economic weighting, and environmental weighting). In all three models, it was found that the Uridan urinal was the most environmentally-friendly, the FalconTM - new alternative second-most, FalconTM -replacement third-most, and the conventional model least environmentally-friendly.

Overall, the results are clear: the Uridan waterless (new installation) is the best choice from both the LCA and LCCA analyses. The conventional urinal is the worst choice of four from both perspectives.

