Influence of LEED on Water Consumption & Cost:
Business Instructional Facility vs. Undergraduate Library

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Introduction and Background:

Rising concern for long-term societal sustainability is a long-awaited relief for those who are intimately involved with the problem. Political buzzwords like “climate change” and “global warming” are underway towards becoming less jargon, and more conversation starters for normal debate. While the topic of water sustainability is inextricably linked to that of energy consumption, the subject has yet to achieve the same status as recycling has, for example, or alternative fuels. In 2008 the University of Illinois at Urbana-Champaign joined many of its peer institutions and pledged to become carbon neutral by 2050. The Illinois Climate Action Plan (iCAP), was developed to reach and benchmark this goal. As part of this agreement, the University of Illinois aims to lower water usage by 50%. The purpose of this paper is to suggest to the University the most economical and efficient means of achieving this goal.

Often considered the premier in environmentally-conscious design, Leadership in Energy and Environmental Design certification (LEED), a development of the U.S. Green Building Council, is an option that any construction, new or old, may pursue if it satisfies certain criteria. Qualified projects must meet three requirements in the Water Efficiency category - including indoor water use reduction, outdoor water use reduction, and building-level water metering - and may pursue an additional 11 points in this division. A minimum of 40 points across six total categories are required to earn the first rank of “Certified”. “Platinum”-certified members must achieve at least 80 points. The University of Illinois is home to eleven LEED facilities – including three Platinum-, three Gold-, and seven Silver-certified projects – with an additional sixteen undergoing the process for certification. For many older buildings, however, the process of retrofitting the entire facility to become LEED-eligible is not cost realistic.

In order to compare and contrast the energy outputs of LEED buildings versus traditional buildings by water use, we decided to choose an example of both which receive similar usage. The Business Instructional Facility (BIF) and the Undergraduate Library (UGL) fit the description, as they often house large numbers of students year-round. BIF, completed 2008, is a 160,000+ square foot relatively new construction, was U of I's first LEED-Platinum certified facility and is home to a green roof, greywater infrastructure (which is not currently in use), and low-flow plumbing in its bathrooms and showers. Construction for the UGL (98,689 sq. ft) was completed in 1969, and the building has not received updating in the bathrooms or water systems since then. Another important proponent of these buildings was that water usage data was available from both.

Methodology:

To determine the effectiveness of LEED certification on lowering water consumption and water costs, water data needed to be obtained from both buildings. Morgan White, the Associate Director of Sustainability at the University of Illinois Facilities & Services, was the primary contact for reaching out to the correct sources in order to find this information (M.White, personal communication, March 1, 2018). To obtain this data from the Business Instructional Facility, communication was made with the building contacts: Kari Cooperider and Carol Young. They provided the following information about the Business Instructional Facility:

1. W2 (UIUC water) from FY 2013 to the present month in KGL
2. CHW1 (UIUC chilled water) from FY 2013 to the present month in KGL
3. W2-San (UIUC Sanitary) from FY 2013 to the present month in KGL
4. Annual water consumption since 2008 (post-LEED Certification)

Each of these were broken down in a total use/cost by month (K. Cooperider, personal communication, April 11, 2018). Carol Young also provided information about the use and traffic of the building by students, RSOs, and other outside organizations (C. Young, personal communication, April 23, 2018).

For the Undergraduate Library, Morgan White and Jeff Schrader, the Associate Dean for Library Facilities, provided the following information:

1. Monthly water consumption since FY 2013 in KGL
2. The average monthly billing days since FY 2013
3. The degree days (heating requirements in the building) since FY 2013
4. Monthly water costs since FY 2013
5. A list of renovations to the building since 2000

In addition, Jeff Schrader also provided information about the patrons the UGL hosts every week (J. Schrader, personal communication, April 23). Once this data was collected, water consumption and cost was analyzed for change over time for the following:

1. UGL water consumption from 2013-2018
2. UGL water cost from 2013-2018
3. BIF water consumption from 2008-2018
4. BIF water cost from 2013-2018
5. UGL vs. BIF water consumption from 2013-2018
6. UGL vs. BIF water cost from 2013-2018

Using the data obtained from the UGL's water consumption and cost, a cost-benefit analysis was first performed to analyze potential costs relating to implementing a step towards LEED certification.

Cost-Benefit Analysis (CBA):

We were provided the total water consumption at the UGL per month, as well as the degree days (a calculation of heating and cooling requirements given temperature proximity to 65 degrees Fahrenheit). As would be expected, these numbers vary greatly each month due to changing temperature, as well as student usage given breaks, proximity to finals, etc.

We approximated the total water usage by bathrooms in the UGL as 50% of total consumption for months during the school year. This number was approximated by creating a ratio between the degree days and total water consumption per month, using the formula $T_{(\text{net consumption})} = b_{(\text{usage})} + (d_{(\text{degree days})} \bullet r)$. Assuming that comparable months each semester yield similar use of the UGL and its facilities (October and March were paired, for example) means that $b_{(\text{usage})}$ can be set equivalent for these months. This yields $T_{m1} - (d_1 \bullet r) = T_{m2} - (d_2 \bullet r)$, then $r = (T_{m1} - T_{m2})/ (d_1 - d_2)$, which generated values ranging from 0.1-0.2, depending on the criteria used to determine comparable months. This ratio was applied to the months during the regular school year using the first formula above; this suggested that water consumption by bathrooms in the UGL rest somewhere between 47-82% of total water usage between October and May. Thus, we assumed a constant 50% throughout this period, in order to be on the low end overall. Due to low library capacity over the summer, 10% was used as the value for this same approximation during the off-term months, and was arbitrarily assigned. These numbers are depicted in the table below (Fig. 2).

With data from Home Depot and CostHelper, we approximated the cost of replacing the toilets and faucets in every bathroom in the UGL. This resulted in an initial upfront cost of $18,300, including labor at an additional 100% fee (the fixtures themselves only cost $9,150).

Using a range of efficiency ratios, we compared costs from Fiscal Year 2016 onward to see how the private and social costs would have compared if these appliances had been installed before FY 16, assuming the ratios above. Then, we included the Social Cost of Carbon (SC-CO2e) at two different values ($12 and $123, per EPA.gov) as well as the Carbon Dioxide equivalent (CO2e), as found by the River Network using the process outlined on leansixsigmaenvironment.org, which assumes a CO2e value of 0.000004082 mt/gal. This data is depicted in the charts below (Fig. 1 & 2).

Value	Unit		Source
200	$	Cost of efficiency toilet	Home Depot
150	$	Cost of efficiency urinal	Home Depot
50	$	Cost of efficiency faucet	Home Depot
0.6	%	Low effiency estimate	WaterSense
0.3	%	High efficiency estimate	WaterSense
12	$/mt	Low SC-CO2 estimate	EPA.gov
123	$/mt	High SC-CO2 estimate	EPA.gov
31	#	Toilets in UGL	
10	#	Urinals in UGL	
29	#	Faucets in UGL	
Upfront Cost @ 2x labor charge			
		$ 18,300	

Figure 1: Upfront values for CBA

Current Data		FY 2016				FY 2017				FY 2018			
		Bathroom Consumption KGL		Cost		Consumption (KGL)		Cost		Consumption (KGL)		Cost	
	JUL	4.93		$ 18.24		4.11		$ 15.41		4.03		$ 15.96	
	AUG	4.61		$ 17.06		2.34		$ 9.27		3.11		$ 13.00	
	SEP	29.85		$ 111.94		33.85		$ 134.05		19.1		$ 79.84	
	OCT	122.95		$ 461.06		42.35		$ 365.71		124.2		$ 519.16	
	NOV	168.95		$ 633.56		156.25		$ 618.75		149.75		$ 625.96	
	DEC	120.3		$ 451.13		13.75		$ 450.45		124.2		$ 519.16	
	JAN	124.1		$ 465.38		117.2		$ 464.11		151.1		$ 631.60	
	FEB	42.6		$ 159.75		26.4		$ 104.55		59.1		$ 247.04	
	MAR	132.5		$ 496.88		126.5		$ 500.94		117.55		$ 491.36	
	APR	108.2		$ 405.75		98.2		$ 388.87		--		--	
	MAY	177.15		$ 664.31		191.35		$ 757.75		--		--	
	JUN	122.75		$ 103.39		97.3		$ 858.77		--		--	
	Total	**1158.89**		**$3,988.43**		**909.6**		**$4,668.61**		**752.14**		**$3,143.06**	

Private Benefits	New KGL	Difference	New $	Dif.	New KGL	Dif.	New $	Dif.	New KGL	Dif.	New $	Dif.
If high efficiency (65%) fixtures used	**463.556**	695.33	**$1,595.37**	$2,393.06	**363.84**	545.76	**$1,867.44**	$2,801.17	**300.856**	451.28	**$1,257.23**	$1,885.84
If lower efficiency (25%) fixtures used	811.223	347.67	$2,791.90	$1,196.53	636.72	272.88	$3,268.03	$1,400.58	526.498	225.64	$2,200.14	$942.92
Social Benefits		Dif. CO2e		Dif. SC-CO2e		(CO2e)		(SC-CO2)		(CO2e)		(SC-CO2)
High approximation (efficiency fixtures, $123 SC-CO2)		2.838608		$349.15		2.227992		$138.14		1.84231		$114.22
Low approximation (less efficient fixtures, $12 SC-CO2)		1.419304		$17.03		1.113996		$69.07		0.92115		$57.11
				Total Dif. ($)				**Total Dif. ($)**				**Total Dif. ($)**
				$2,742.21				$2,939.30				$2,000.06
				$1,213.56				$1,469.65				$1,000.03

	Consumption (KGL)		Cost($)					
SUM FY16-18	2820.63		**$11,800.11**					
If low-flow fixtures were installed								
	New (KGL)	Difference	New($)	Difference				
Private	1128.252	1,692.38	$4,720.04	**$7,080.06**	or	**$2,574.57**	per year	expect payoff in 7 years
	1974.441	846.19	$8,260.07	**$3,540.03**	or	**$1,287.28**	per year	payoff in 14 years
	Diff. CO2e	Diff. SC-CO2		Overall $ saved 2016-2018				
Social	6.908906089	$601.51		**$7,681.57**	or	**$2,793.30**	per year	payoff in 6.5 years
	3.454453045	$143.21		**$3,683.24**	or	**$1,339.36**	per year	payoff in 13.5 years

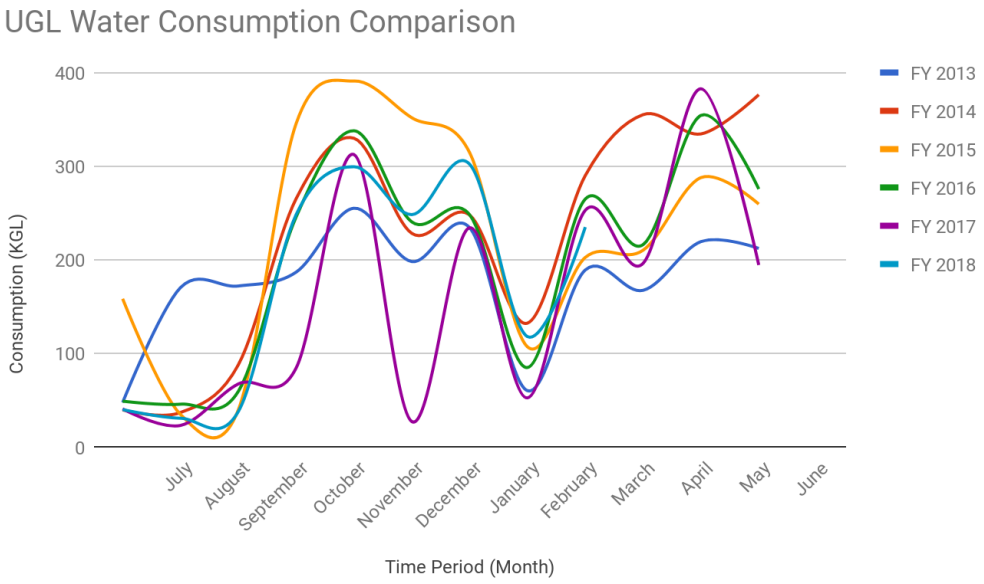
Figure 2: Initial costs from FY 16-18. Results from CBA expect payoff for replacing UGL fixtures within 7-14 years. Social CBA does not include the embodied energy of new fixtures.

Combining these different analyses could give a conclusive representation on the economic and environmental impacts of LEED certified vs. non-LEED buildings on campus.

Our Cost Benefit Analysis offered a systematic approach to estimate the strengths and weaknesses of using alternative low-flow toilets and faucets. Using the CBA, we were able to determine the best options that offer the most sustainable and efficient approach to achieve environmental benefits while considering economic savings. From the Cost-Benefit Analysis, we were able to calculate and compare the benefits and costs of the influence of low-flow units to determine that the low-flow fixtures would reach economic payoff in 7 years at best, and 14 years at worst. Additionally, the social benefit cost will pay off in 6.5 to 13.5 years. A payoff in 7 to 14 years is worth the cost of installing low-flow toilets, justifying the replacement of low-flow units in the UGL. After conducting background research and utilizing the cost-benefit analysis, we recommend the adoption of low-flow units in the UGL.

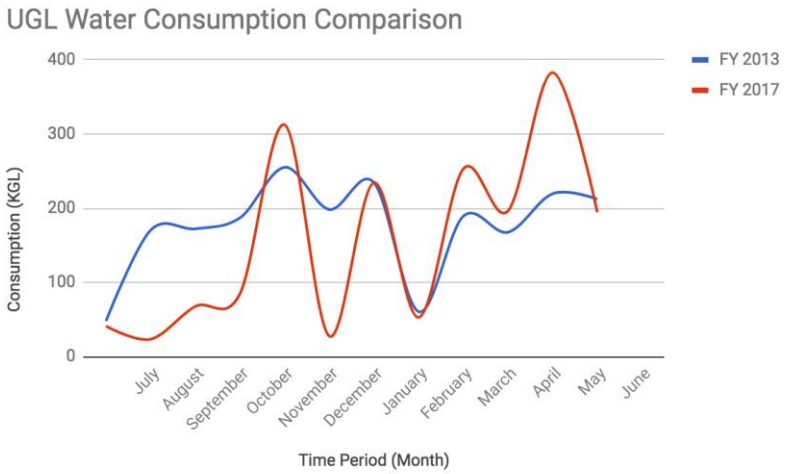
Results and Discussion:

After the correct data was received from the university, the Undergraduate Library was then analyzed over the years for changes in water consumption. According to Jeff Schrader, approximately 31,000 patrons use the UGL every week (J. Schrader, personal communication, April 23). The first comparison was with every year since FY 2013, as can be seen in the graph below.



Graph 1: UGL Water Consumption from the Fiscal Years 2013-2018

The overall trend is similar in the sense that there is a dip in water consumption in the summer months (June, July, August) and in the mid-winter months (December, February), correlating to the months in between the Fall and Spring semesters. However, there is great variability over the five years of water consumption. The graph below shows a more detailed analysis of this change by comparing FY 2013 water consumption to the water consumption in 2017.

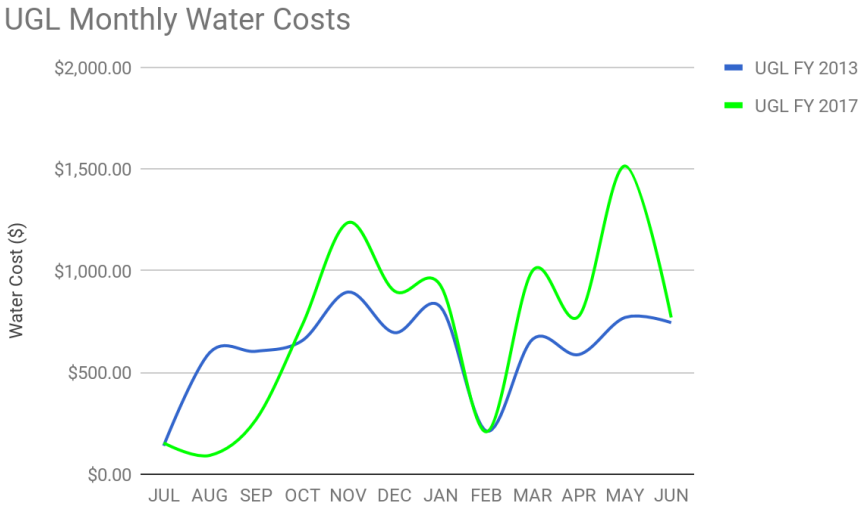


Graph 2: UGL Water Consumption Change from FY 2013 to FY 2017

While FY 2017 has more variability in water consumption, the yearly total was significantly less than that of FY 2013. FY 2017 had an overall consumption of 1,870.8 KGL, dropping from 2,114.8 KGL in FY 2013.

According to the data, over the course of FY 2013 to FY 2017, there was a significant per capita decrease in water consumption at the UGL. Because there are approximately 31,000 people who use the library on a weekly basis, we were able to calculate the per capita usage of water in both FY 2013 and FY 2018. A total of 2,114,800 gallons was used in in 2013 (40,669 gal/week) and 1,870,800 gallons of water were used in FY 2017 (35,977 gal/week). On an average day, 1.31 gal of water was used per patron in FY 2013 and 1.16 gal of water was used per patron in 2017. This is a 0.15 gallon difference between FY 2013 and FY 2017. Overall, FY 2017 had a lower overall and per capita consumption of water in comparison to FY 2013. This may be due to changing foot traffic over the years or the addition of other newer libraries and study spaces on campus.

The monthly water cost at the Undergraduate Library increased since FY 2013 due to potential increase water cost per gallon. However, although there was an overall increase in the yearly water cost from $7,394.96 in FY 2013 to $8,587.72 in FY 2017, there were some months that were lower in water cost. These seem to correlate with the months of decreased water consumption. The following graph displays these changes in monthly water costs from FY 2013 to FY 2017.

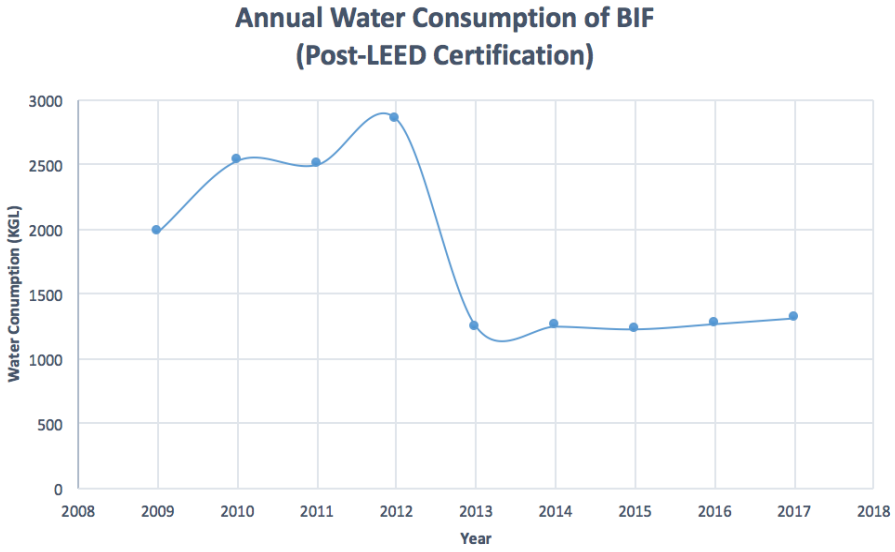


Graph 3: UGL Monthly Water Cost Change from FY 2013 to FY 2017

For the post-LEED certified Business Instructional Facility, Carol Young stated that there are about 3,000 undergraduate and 2,000 graduate students that regularly use the building (C. Young, personal communication, April 23, 2018). In addition, there are various RSOs that reserve rooms in the building for meetings, other organizations utilize the space for outside events, and faculty and staff that use the building regularly. The annual water consumption from FY 2009 to FY 2017 started off increasing in consumption until there was a sharp decline from 2,842 KGL in FY 2012 to 1,246.40 KGL in FY 2013. After this decline, the water consumption has stayed relatively contact.

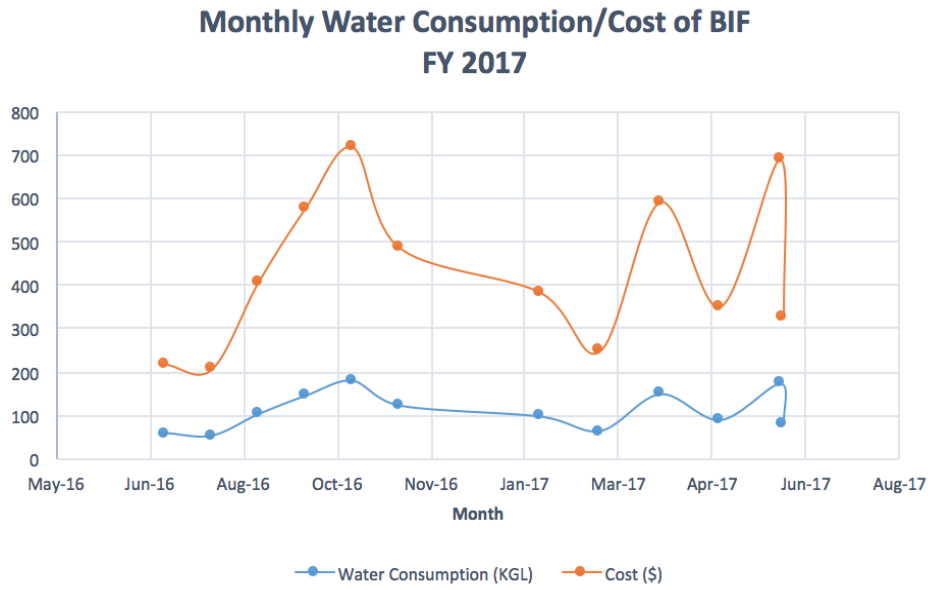
Though BIF water consumption data was variable, the water consumption over time, still shows some trends. Not surprisingly, BIF water consumption is low in the summer months, July and August, in both FY 2013 and FY 17. Both years show a peak in November, a popular time for midterms and studying. BIF likely has heavier traffic during this time due to RSO meetings and students coming together to utilize the BIF's classrooms and atrium to study. In February, both years show a drop in water usage, though class is in session in February. In May, especially

May 2017, water consumption spikes. This may be because students make use of the BIF to study for spring final exams.



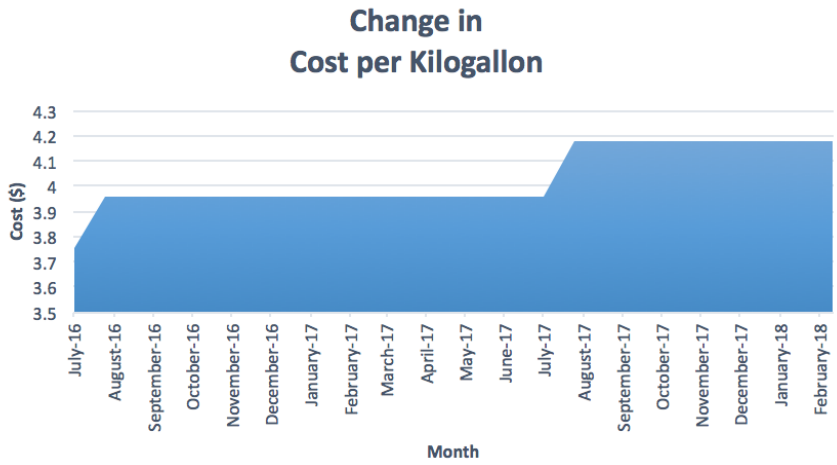
Graph 4: Annual Water Consumption of Post-LEED Certified BIF (FY 2009 to FY 2017)

Comparing the last year of water consumption in BIF to the monthly water cost, there seems to be a correlation in the movement of water costs to the movement of water consumption by month.



Graph 5: Monthly Comparison of BIF's Water Cost and Consumption in FY 2017

Even so, there were increases in the cost per kilogallon in August 2016 and in August 2017, as displayed in the graph below. This price raise can be seen in the August 2016 month and forward in the graph above. Because of the increase in price of water, the university and its users may need to significantly lower water consumption. At the current rate of water usage, water bills will only go up, and changes need to be made so that the cost of water increase is offset.

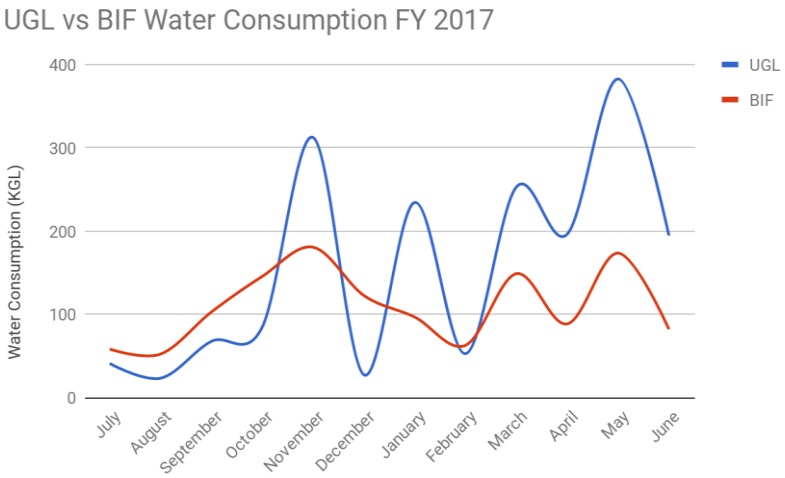


Graph 6: Change in BIF's Water Cost per Kilogallon in FY 2017

Comparing the Undergraduate Library to the Business Instructional Facility can give an insight into the differences in water consumption and cost between LEED-certified and non-LEED buildings. The graph below compares the water consumption of these two buildings by month in FY 2017. Compared to BIF, UGL has much more variability in water consumption per month. While BIF surpassed the UGL in water consumption during the months of July to October, December, and February, the overall water consumption of BIF was 1,315.8 KGL as compared to UGL's overall water consumption of 1,870.8 KGL.

Both the Undergraduate Library, a non-LEED certified building, and the Business Instructional Facility, a LEED-certified building, show differences in consumption for FY 2013

and FY 2017. The UGL seems to have more variability in foot traffic as it is typically used by mostly undergraduate students, though it is open to all University affiliates. The BIF seems to have less variability in foot traffic, though it is also difficult to pinpoint a number as there are graduate and undergraduate scheduled classes as well as visitors who study or hold meetings. Overall, average consumption decreased from FY 2013 to FY 2017 across both buildings though there was high variability.

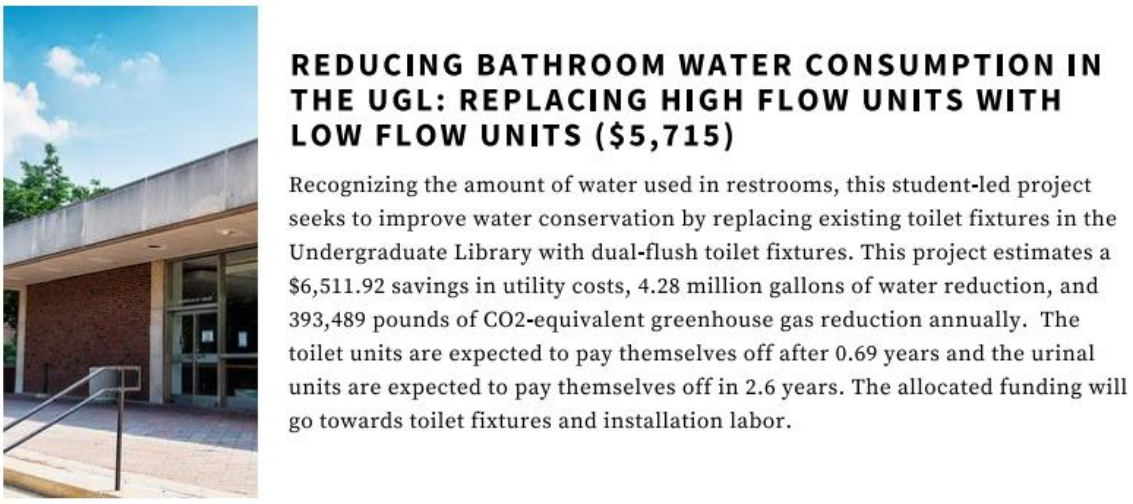


Graph 7: Comparison of UGL and BIF's Water Consumption in FY 2017

When comparing the Undergraduate Library to the Business Instructional Facility in terms of water cost in FY 2017, UGL turned out to be paying $3,389.43 more than BIF's water costs of $5,198.29. On a monthly basis, as can be seen below in the graph, BIF does pay more than UGL in July, August, September, and February.

Making the most economical decisions to lower water usage will lower both cost of water and environmental impact of water. UGL can benefit from saving water by implementing low-flow toilets and faucets. Low-flow appliances will lessen water consumption, therefore also lowering overall costs of water. A Student Sustainability Committee (SSC) grant worth $5,715 has been approved to fund low-flow toilets and faucets (Student Sustainability Committee 2018).

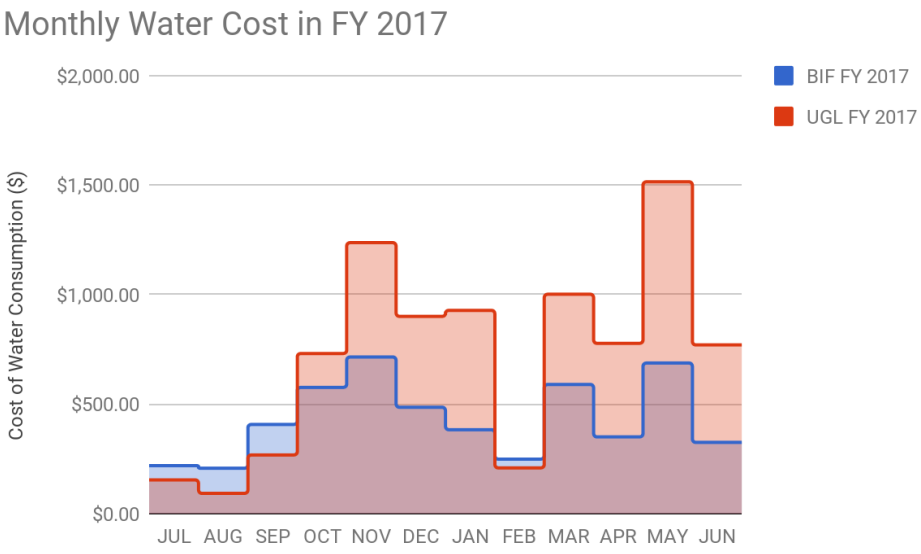
This change is to be implemented over the course of the Fall 2018 school year, and will save an estimated $6,512 in utility costs and 4.28 million gallons of water annually. In comparison, Platinum-certified BIF already has low-flow faucets and toilets. The result of low-flow units is shown through UGL paying $3,389.43 more than BIF in FY 2017.



REDUCING BATHROOM WATER CONSUMPTION IN THE UGL: REPLACING HIGH FLOW UNITS WITH LOW FLOW UNITS ($5,715)

Recognizing the amount of water used in restrooms, this student-led project seeks to improve water conservation by replacing existing toilet fixtures in the Undergraduate Library with dual-flush toilet fixtures. This project estimates a $6,511.92 savings in utility costs, 4.28 million gallons of water reduction, and 393,489 pounds of CO_2-equivalent greenhouse gas reduction annually. The toilet units are expected to pay themselves off after 0.69 years and the urinal units are expected to pay themselves off in 2.6 years. The allocated funding will go towards toilet fixtures and installation labor.

Figure 3: Student Sustainability Committee 2018-2018 Annual Report



Graph 8: Comparison of Monthly Water Cost for UGL and BIF in FY 2017

Since each building has significantly different patron use and square footage, an additional analysis was completed comparing the yearly cost per square foot in each building. Due to minimal data received about the monthly costs in previous years in BIF, a monthly cost per square footage was also done in the current fiscal year. This was also done to visualize a more accurate representation of cost per square foot due to price increase in water use. The following charts show the yearly and monthly costs per square foot in each building.

Yearly Cost Per Square Foot			
UGL		BIF	
Fiscal Year	Cost/Foot^2	Fiscal Year	Cost/Foot^2
2013	$0.07	*N/A*	*N/A*
2014	$0.10	*N/A*	*N/A*
2015	$0.10	*N/A*	*N/A*
2016	$0.09	*N/A*	*N/A*
2017	$0.09	2017	0.03248931

Chart 1: Yearly Water Cost per Square Foot in UGL and BIF from FY 2013 to FY 2017

Monthly Cost Per Square Foot		
	UGL	BIF
FY 2018	Cost/Ft^2	Cost/Ft^2
July	$0.0016	$0.0016
August	$0.0013	$0.0015
September	$0.0016	$0.0015
October	$0.0105	$0.0042
November	$0.0127	$0.0044
December	$0.0105	$0.0036
January	$0.0128	$0.0026
February	$0.0050	$0.0020
March	$0.0100	--
April	$0.0089	--
May	--	--
June	--	--
Monthly Average	$0.0075	$0.0027

Chart 2: Monthly Water Cost per Square Foot in UGL and BIF in FY 2018

While the UGL has seen a decrease in the cost per square foot, it is tripled the annual cost per square foot of BIF in FY 2017. When looking more in depth at the monthly cost per square foot in FY 2018, UGL surpasses each month in cost except in July when the two buildings are

the same and when the UGL is lower in August. Overall, the monthly average of UGL is again almost tripled the cost per square foot of BIF.

Conclusion:

In order to evaluate the influence of having LEED certification on water consumption and cost in the Undergraduate Library and the Business Instructional Facility, we proposed two questions to answer. The first asked if the economic and environmental savings outweigh the costs of infrastructure and upkeep. To this questions, we hypothesized that yes, the savings would outweigh the costs. After conducting this project, we found that yes, the savings do outweigh the costs, but it takes time due to the high upfront costs. The data we collected support green architecture to save monetarily and reduce water usage. The second question we proposed asked if being LEED certified is a crucial step in being useful in an economic and environmental sustainability context. We hypothesized that yes, being LEED certified is necessary. After carrying out the project, we found that no, but small transitions can make a difference. We found that buildings that are LEED certified do shift us toward our iCAP goals of reducing water consumption by 50% by 2050, however, more needs to be done. The students of the University have already recognized the need for the UGL to improve upon water resource usage and is moving forward with an SSC funded project to install low-flow units throughout UGL that will result in lower utility costs and water consumption rates. Additionally. these findings show the economic and environmental benefit of LEED-certification on buildings on University of Illinois' campus, however, they do not factor in the social cost of water, which is highly important to consider in the face of our global water deficit.

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