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A Framework for Assessing the Economic Feasibility of LEED for Homes Guidelines for Water Efficiency

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ABSTRACT

Sustainable practices have been on the rise during the last decade. From recycling to alternative energy sources, many studies have been conducted to incorporate green practices into people's daily lives. However, cost efficiency can be a significant deterrent to begin or continue these practices. Homes are responsible for the consumption of a large portion of water in the United States. As such there is a need for more studies directed toward the assessment of the practical implementation of water efficiency. This study follows LEED v4 for homes guidelines to examine the feasibility of adopting green practices for water reduction. The paper presents a framework for a feasibility study on the utilization of efficient water fixtures in homes. The results show that the utilization of efficient water fixtures as recommended by LEED v4 for homes can be the most economic alternative on the long run.

INTRODUCTION

Water is a vital and critical resource to mankind. Despite the drought that has impacted 26.8% of the U.S. (drought.gov), Americans continue to consume large amounts of water. In 2010, it was estimated that the daily consumption of water in the U.S. is 355 billion gallons of which 3.6 billion gallons were used domestically (water.usgs.gov). Finding new and feasible methods for conserving water has become a persistent need to preserve this precious resource. As such, efficiency in water usage has become a major and a critical criterion for measuring sustainable performance and green evaluation of buildings. The U.S. Green Building Council (USGBC) has established a set of criteria for the evaluation of water efficiency in buildings. Similarly, the Institute of Sustainable Infrastructure has emphasized the importance of preserving water in different sections of its Envision Guidance manual. Since the residential sector is a major consumer of water in the U.S., USGBC has designated a set of performance evaluation criteria for water efficiency for residential buildings in LEED v4. The Environmental Protection agency (EPA) and USGBC have been advocates for the installation of water-efficient fixtures in buildings. Although these efficient fixtures come at an additional cost, it is argued that it can be more economic on the long run. This paper aims to provide a feasibility study for the installation of water-efficient fixtures in homes using the present worth analysis (PWA). The study was implemented to different cities in Texas to compare the economic savings associated with the water-efficient fixtures compared to traditional ones.

PROBLEM

The literature review included many studies that focused on green methods and their overall assessment. Most studies adopted the LEED rating system as a reference for the evaluation of green building performance, and financial feasibility. However, the main focus in these studies was on the energy section of the LEED rating system. Due to limitation of the available information on the financial and economic aspects of the different sections of the LEED rating system, it is difficult to assess the feasibility of the different green alternatives and the savings that can be achieved. Although the benefits of green building have been proven through plenty of research, many individuals are still hesitant to adopt efficient water fixtures in their homes. This is due to the high initial cost associated with the installation of these fixtures. However, the majority are unaware of the monetary benefits that green building can bring to tenants and home owners.

OBJECTIVE

As such, there is need to verify and assure the economic feasibility of the investment in efficient water systems. This study focuses on the assessment of the economic feasibility of water-efficient low-rise residential homes using the LEED v4 rating system as a reference for the analysis. Texas was selected for this study as the second most populated state in the U.S.

LITERATURE REVIEW

Several studies have addressed the efficiency of green methods. However, very few of them addressed the water efficiency. One study presented a software (Ecologic3) that performs a cost-benefit analysis for the implementation of every aspect in LEED v4 (Lockwood, 2014). A similar paper focused on the life-cycle assessment of the project in the preconstruction phase to optimize the strategies for green building using multi-objective genetic algorithms (Wang et al, 2006). A different study addressed financial benefits of green building with the main focus was on the decreased return on investment for energy consumption as well as the increased productivity and health (Kats, 2012). One study showed the different methods that can and have been used for conserving and reducing the amount of electricity used in buildings in Egypt. The study presented different methods of alternative energy and the pros and cons of each (Salama, 2008).

A number of studies focused on the cost and value of LEED-certified buildings. A study discussed the cost of a LEED-certified buildings versus the cost of a non-certified ones; the study presented cost figures for accurate comparison between the two types of buildings (Butler, 2008). The value of a green building was also explored in a different study that presented an equation for calculating the increase in rent rates of LEED-certified office spaces (Eichholtz et al, 2010). Another study based on the old LEED rating system utilized regression analysis to calculate the different cost premiums when using green building design (Tatari and Kucukvar, 2011). Thilakaratnea and Lewa (2011) presented a study showing how buildings in Asia have outperformed building in the United States in several LEED categories. Alyami and Rezgui (2012) and Briet and Abdel-Raheem (2013) compared different LEED rating systems. A study by Ward et al. (2012) showed that there are many ways to achieve points for water efficiency in the LEED rating system using innovative methods.

Another study by Garde (2009) examined the LEED rating system to find the efficiency and validity of attempting to become certified.

Another group of studies focused on the WaterSense label which is a requirement for the majority of the most commonly used fixtures in a residence. These articles provide information on duration, warranty and efficiency of these fixtures. (Hecht and Sanders 2007; Devine et al. 2007; Grumbles 2008; Whitehead et al. 2008; Lee 2013; Do et al. 2014; and Schein et al. 2017).

LEED RATING SYSTEM

Homes & multifamily lowrise, and multifamily midrise

In the LEED v4 for Building Design and Construction there are two main sections, Homes & Multifamily Lowrise, and Multifamily Midrise. Home & Multifamily Lowrise refers to residential buildings that are three or less stories high while Multifamily Midrise buildings are 4 to 8 stories and have at least 50% residential space. These two sections have very similar project checklists with the same categories as well as the ultimate amount of possible points available. However, the total points obtainable for a few of the categories vary between the two sections. Table 1 displays the total points available per category for both Homes & Multifamily Lowrise, and Multifamily Midrise.

Table 1. Total Category Points

Type	Location & Transportation	Sustainable Sites	Water Efficiency	Energy & Atmosphere	Materials & Resources	Indoor Environmental Quality	Innovation	Regional Priority
Homes and Multifamily Lowrise	15	7	12	38	10	16	6	4
Multifamily Midrise	15	7	12	37	9	18	6	4

The water efficiency section of LEED for Homes only has one requirement, which is water metering. Water metering for single family homes can use a whole-house water meter. Single family attached homes can also install a whole-house water meter if landscaping is commonly managed. Multifamily homes can choose between installing a water meter for each unit or for the entire building.

Water efficiency

Out of the total 110 points that can be obtained in both the homes and multifamily low-rise, and the multifamily high-rise project checklist, water efficiency accounts for only 10-12 of those points. These points can be rather easily obtained if the proper planning is implemented (LEED, 2016).

There are three requirements for the water efficiency portion of the LEED for Homes checklist. The first requirement is water metering; however, homes that only use well water are exempted from this requirement. The second requirement dictates water pressure in any single-family unit cannot exceed 60 psi, and the final requirement is obtaining a minimum of three points in order to be gain the LEED certification.

There are two pathways available to follow in water efficiency. However, the Total Water Use pathway is the mandatory procedure to follow if the shower fixtures consume more than 2.5 gallons per minute (gpm) or if the project includes pools or other outdoor water features.

Total Water Use is subjected to a scoring based on the total percentage of water reduction and can earn a total of 12 points. There are four requirements for Total Water Use. These requirements are 1) the reduction of water use by at least 10%, 2) water softeners be demand initiated, 3) the indoor monitoring of water using the water reduction calculator found in the USGBC website (LEED, 2014) as well as 4) the outdoor monitoring of water using the EPA WaterSense Landscape budget tool found in the EPA website (EPA, 2017).

There is a baseline for the indoor water consumption of fixtures per person, per day in the LEED v4 for Homes Design and Construction, see Table 2. The point awarding for Total Water Use begins at one point given for ten percent water reduction and assigns a point for every five percent water reduction from the initial ten percent.

Table 3. Total water, Indoor Water Consumption Baseline

Water fixture	Baseline flush/flow rate		Estimated fixture usage (per person per day)	Estimated water	
Shower	2.5 gpm	9.5 lpm	6.15 min	15.4 gallons	58
Faucet	2.2 gpm	8.3 lpm	5 min	11 gallons	41
Toilet	1.6 gpf	6 lpf	5.05 flushes	8 gallons	30
Clothes Washer	9.5 WF	9.5 WF	.37 cycles	15.1 gallons	57
Dishwasher	6.5 gpc	24 lpc	.1 cycles	.7 gallons	2

The second available pathway is a two-step procedure that separates the indoor and outdoor water consumption. This procedure has a total of ten points available, six points available in the indoor water portion and four in the outdoor water. The requirement for the indoor water is to have faucets and faucet aerators, shower head fixtures and fitting as well as toilet fixtures and fitting all WaterSense labeled. A complete list of WaterSense labeled products can be found in the EPA Website (EPA 2017).

A point is given for having a clothes washer that is Energy Star qualified. Energy Star qualified products are both water and energy efficient and thus reduce the amount of water and electricity required to operate. Energy Star qualified products can be found in the Energy Star website (Energy Star). The remaining five points can be gained depending on the flush and flow rates of the sink, shower and toilet water fixtures.

METHODOLOGY and FRAMEWORK

Water Efficiency section of the LEED v4 rating system was studied and the requirements and points were taken into consideration. The requirement that demands the greatest money investment is having faucets, showers and toilets Water Sense labeled. The average cost of these fixtures as well as their installation cost and estimated lifetime were obtained. The identified costs were categorized in 4 major groups, as shown in Table 4.

A sample of 25 cities in Texas is selected; the water and sewer rates for those counties was obtained. The water consumption was calculated for efficient and traditional water fixture using the Home Water Works Water Calculator (home-water-works.org). Once the water usage and rates were obtained, the monthly usage cost of water was calculated using the following Equation 1.

$$W = B_w + (T_w - I_w) * R_w \qquad (1)$$

Where, W is the total cost of water, B_w is the base cost or service fee, which usually covers a certain amount of water consumption; T_w is the total amount of water used per month; I_w is an initial amount of water covered by the base rate; and R_w is the additional fee charged after exceeding the initial amount, and it is usually assessed per 1,000 gallons in exceed of the initial limit. It should be noted that some counties do not have the initial water consumption allowance (I_w) while other counties have a standard fee for either water or sewer services or both. The sewer cost is calculated according to Equation 2; where S is the total cost of sewer. The rest variables in this equation (B_s, T_s, and R_s) are the same but they stand for the sewer base cost and rate. In calculating sewer service cost, there is no initial allowance. Therefore, the term (I) is missing is Equation 2.

$$S = B_s + T_s * R_s \qquad (2)$$

Once all the costs were acquired, interest rates were obtained with respect to housing mortgages and green building rate of returns were determined. The discount rates used were 1%, 2%, 3%, 4%, and 5%. Two cashflows were established using the monthly water cost, the cost of installation, and the average price of the fixtures. The first cashflow represents the efficient fixtures while the other cashflow is for traditional (non-efficient) fixtures. Present Worth Analysis (PWA) was conducted to compare the two alternatives.

ANALYSIS

A separate cashflow was created for the efficient and the traditional fixture, as shown in Figure 2. The two cashflows are identical in term of number and timing of payments. However, payments have different values.

Study parameters

The initial payment "P" in the cashflow represents the initial cost of the fixtures and of installation; these fixtures include the shower, toilet, washing machine and both kitchen and bathroom faucets. Since the life expectancy of the shower and all faucets is 10 years, at the ten-year mark in the cashflow the cost of those fixtures and their installation costs is represented in the cashflow as R. At the 20-year mark, all these fixtures are disposed at no salvage value. It should be noted that the toilet lasts for 20 years. Table 4 summarizes the different study parameters used in the PWA. The efficient fixtures have a higher cost compared to the traditional ones. However, the cost of installation is the same. The total cost of efficient fixture and installation for a typical house hold is $2,528 while the cost of the traditional fixtures and their installation is $1,748. The monthly base charge of water (B_w) for the 25 cities varied between $0, which indicates no base fee, and $40 for a quantity of water (I_w) that varied between 0 and 3,000 gallons. The monthly rate for water (R_w) ranged between $1.18/1000 gal and $8.25/$1000 gal, as shown in Table 5. $62.2 and for the traditional fixtures from $12.5 to $67.7.

Table 4. Values of the Different Study Parameters

Category	Study Parameters	Value
1	**Initial Cost - Cost of Fixtures (Including Installation)**	
1-1	*Traditional*	$1,748
1-2	*Efficient*	$2,528
2	**Water Cost - Cost of Water Consumption + Sewage**	
2-1	Amount of Water Consumption/Household *Traditional*	4,455 Gallon/Month
2-2	Amount of Water Consumption/Household *Efficient*	3,300 Gallon/Month
2-3	Water Rate	Varies - See Table 2
2-4	Sewage Rate	Varies -See Table 2
3	**Replacement Costs**	
3-1	Every 10 Years - All fixtures Except Toilets - *Traditional*	$1,200
3-2	Every 10 Years - All fixtures Except Toilets - *Efficient*	$1,880
4	**Residual Value (Salvage)**	
4-1	*Traditional* Fixtures @20 years	$0
4-2	*Efficient Fixtures* @20years	$0
5	**Rates**	
5-1	Annual Water Rate Increase (g1)	5.50%
5-2	Annual Sewage Rate Increase (g2)	6.10%
5-3	Nominal Discount Rate for 2017 (i)	3.00%
6	**Service Period**	20 Years

The monthly base charge of sewer (B_s) ranged between $0, which indicates no base fee and $48.82, which is a flat rate. The monthly rate for water (R_s) ranged between $1.18/1000 gal and $8.25/$1000 gal, as shown in Table 5. $62.2 and for the traditional fixtures from $12.5 to $67.7.

Assumptions

Since the monthly water consumption, calculated using the Home Water Works water consumption calculator, is assumed to be the same in all cities, the difference in annual water consumption cost is attributed to the differences in the water base fee costs and rates set by the county. As such, cities with significantly higher base costs and rate for water supply were the ones that proved efficient fixtures to be feasible at a lower discount rates. It is also assumed that water for irrigation is metered separately which renders the quantity of wastewater identical to the quantity of water consumed. The monthly water consumption using the efficient fixtures is 3,300 gal./month while the water consumption using traditional fixtures is 4,455 gal./month, as shown in Table 4.

Table 5. Water and Sewage Rate for the Selected 25 Cities in Texas

No.	City	Water			Sewage	
		Base H_2O Supply (gal.)	H_2O Base Rate ($)	H_2O Cost/1,000 gal.	Base Rate ($)	Sewer Cost/1,000 gal.
1	Abilene	0	$ 23.00	$ 3.00	$ 12.00	$ 1.55
2	Amarillo	3,000	$ 27.19	$ 3.62	$ 15.80	$ 1.82
3	Atlanta	2,000	$ 14.63	$ 5.42	$ 17.21	$ 6.18
4	Austin	0	$ 15.00	$ 3.18	$ 10.30	$ 10.35
5	Beaumont	2,000	$ 20.99	$ 3.25	$ 21.74	$ 2.30
6	Brownwood	2,000	$ 28.00	$ 8.25	$ 3.50	$ 2.35
7	Bryan	0	$ 8.31	$ 2.76	$ 7.88	$ 3.80
8	Childress	1,500	$ 10.82	$ 2.86	$ 8.50	$ 3.55
9	Corpus Christi	0	$ 24.20	$ 4.00	$ 18.98	$ 1.92
10	Dallas	0	$ 10.56	$ 1.90	$ 9.35	$ 5.31
11	El Paso	2,992.21	$ 10.34	$ 1.99	$ 32.25	$ 1.77
12	Ft. Worth	0	$ 26.38	$ 2.65	$ 11.75	$ 4.53
13	Houston	2,000	$ 10.24	$ 5.12	$ 10.00	$ -
14	Laredo	2,000	$ 20.55	$ 1.97	$ 35.03	$ -
15	Lubbock	0	$ 26.71	$ 4.76	$ 19.49	$ 3.17
16	Lufkin	3,000	$ 32.83	$ 2.57	$ 48.42	$ -
17	Odessa	0	$ 40.00	$ 5.55	$ -	$ -
18	Paris	0	$ 19.22	$ 3.54	$ 23.60	$ -
19	Pharr	1,000	$ 9.00	$ 1.45	$ 9.00	$ 1.27
20	San Angelo	0	$ 20.00	$ 2.83	$ 19.51	$ 1.24
21	San Antonio	0	$ 22.90	$ 1.18	$ 16.22	$ 4.16
22	Tyler	2,000	$ 6.00	$ 3.52	$ 8.30	$ 3.95
23	Waco	2,000	$ 16.00	$ 3.70	$ 13.00	$ 5.00
24	Wichita Falls	0	$ 36.28	$ 2.83	$ 7.53	$ 1.75
25	Yoakum	2,000	$ 18.35	$ 3.60	$ 19.71	$ 3.74

Results

The monthly cost of water (A_{water}) consumption for the efficient fixtures ranged from $12.33 to $62.2 and for the traditional fixtures from $14.32 to $67.7. The monthly cost of sewer (A_{sewage}) bill for the efficient option ranged from $0 to $51.72 and for the traditional fixtures from $0 to $62.05. It should be noted that some counties do not have a separate charge for sewer. The replacement cost of efficient fixture (excluding toilet) after ten year (R) is $1,880, and for the traditional fixtures (excluding toilet) is $1,200. Both water and sewer costs were assigned an annual increase (g) of 5.5% and 6.1% respectively (AWWA 2014). That is why the cashflow for the annuity takes the shape of a geometric gradient. The present worth values of each group of fixtures were calculated according to Equation 5.

$$PW = P_0 + R*(P/F, i, n) + A_{water}*(P/A, g, i, n) + A_{sewage}*(P/A, g, i, n) \quad (5)$$

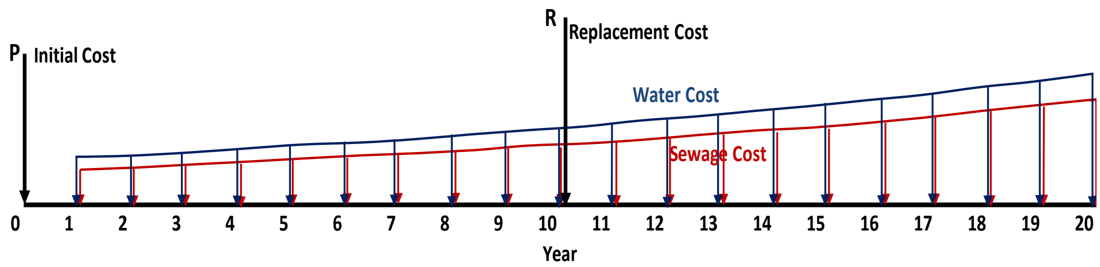

Figure 2. General Form Cashflow

Out of the 25 cities selected to represent Texas, the PWA proves the efficient fixtures more economically feasible on the long run (20 years) at discount rate of 3% in 17 cities. All the calculation for the 25 cities are shown in Table 6. As the study period increased, the number of cities reporting traditional fixtures to be more economically feasible decreased. At 40-year period analysis, all cities reported the efficient fixtures to be more economically feasible.

Table 4. PWA for 25 Cities at Discount Rate of 3%

No.	City	Water (A_{water})		Sewer (A_{sewage})		PWA		Best Option
		Traditional Monthly Cost	Efficient Monthly Cost	Traditional Monthly Cost	Efficient Monthly Cost	Traditional	Efficient	
1	Abilene	$ 38.00	$ 35.00	$ 19.75	$ 18.20	$ 21,261.07	$ 21,278.34	Traditional
2	Amarillo	$ 34.43	$ 30.81	$ 24.90	$ 23.08	$ 21,858.04	$ 21,593.81	Efficient
3	Atlanta	$ 30.89	$ 25.47	$ 48.11	$ 41.93	$ 28,437.12	$ 26,172.59	Efficient
4	Austin	$ 30.90	$ 27.72	$ 62.05	$ 51.70	$ 33,053.19	$ 30,103.59	Efficient
5	Beaumont	$ 30.74	$ 27.49	$ 33.24	$ 30.94	$ 23,473.09	$ 23,164.77	Efficient
6	Brownwood	$ 52.75	$ 44.50	$ 15.25	$ 12.90	$ 24,344.81	$ 22,469.99	Efficient
7	Bryan	$ 22.11	$ 19.35	$ 26.88	$ 23.08	$ 18,693.95	$ 18,041.31	Efficient
8	Childress	$ 19.40	$ 16.54	$ 26.25	$ 22.70	$ 17,645.47	$ 17,044.53	Efficient
9	Corpus Christi	$ 44.20	$ 40.20	$ 28.58	$ 26.66	$ 26,104.02	$ 25,688.91	Efficient
10	Dallas	$ 20.06	$ 18.16	$ 35.90	$ 30.59	$ 21,042.33	$ 20,156.77	Efficient
11	El Paso	$ 14.32	$ 12.33	$ 41.10	$ 39.33	$ 20,983.17	$ 21,240.76	Traditional
12	Ft. Worth	$ 39.63	$ 36.98	$ 34.40	$ 29.87	$ 26,612.65	$ 25,752.62	Efficient
13	Houston	$ 25.60	$ 20.48	$ 10.00	$ 10.00	$ 14,191.83	$ 14,064.67	Efficient
14	Laredo	$ 26.46	$ 24.49	$ 35.03	$ 35.03	$ 22,738.47	$ 23,587.79	Traditional
15	Lubbock	$ 50.51	$ 45.75	$ 35.34	$ 32.17	$ 30,296.31	$ 29,232.10	Efficient
16	Lufkin	$ 37.97	$ 35.40	$ 48.42	$ 48.42	$ 30,735.95	$ 31,399.28	Traditional
17	Odessa	$ 67.75	$ 62.20	$ -	$ -	$ 23,949.90	$ 23,689.45	Efficient
18	Paris	$ 36.92	$ 33.38	$ 23.60	$ 23.60	$ 22,199.88	$ 22,562.51	Traditional
19	Pharr	$ 14.80	$ 13.35	$ 15.35	$ 14.08	$ 12,613.73	$ 13,204.12	Traditional
20	San Angelo	$ 34.15	$ 31.32	$ 25.71	$ 24.47	$ 22,039.20	$ 22,211.73	Traditional
21	San Antonio	$ 28.80	$ 27.62	$ 37.02	$ 32.86	$ 24,122.15	$ 23,840.22	Efficient
22	Tyler	$ 16.56	$ 13.04	$ 28.05	$ 24.10	$ 17,360.54	$ 16,422.69	Efficient
23	Waco	$ 27.10	$ 23.40	$ 38.00	$ 33.00	$ 23,919.36	$ 22,578.37	Efficient
24	Wichita Falls	$ 50.43	$ 47.60	$ 16.28	$ 14.53	$ 23,966.36	$ 23,970.18	Traditional
25	Yoakum	$ 29.15	$ 25.55	$ 38.41	$ 34.67	$ 24,690.47	$ 23,797.29	Efficient

CONCLUSION

This study explored the feasibility of using efficient water fixtures as an alternative option for preserving and reducing the consumption of water. The paper explored the guidelines of LEED v4 for Building Design and Construction for the water efficiency in residential building. A PWA was conducted to assess the economic feasibility of installing water-efficient fixtures in residential buildings in 25 different cities in Texas. The initial finding of this study show that efficient water fixture can be very economic on the long run. The analysis of the data using the PWA also shows that the efficient fixtures are more feasible in areas with high water and sewer costs. At a discount rate of 3%, in almost 70% of the cities considered in this study water-efficient fixtures were more economic than the traditional ones. It is recommended to invest in water-efficient fixtures and appliances and follow the LEED v4 Rating System in areas with high water and sewer rates.

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