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Engineering Management Journal

ISSN: 1042-9247 (Print) 2377-0643 (Online) Journal homepage: http://www.tandfonline.com/loi/uemj20

To LEED or Not to LEED: Analysis of Cost Premiums Associated With Sustainable Facility Design

David M. Nyikos, Alfred E. Thal, Michael J. Hicks & Sonia E. Leach

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David M. Nyikos, Air Force Institute of Technology
Alfred E. Thal, Jr., Air Force Institute of Technology
Michael J. Hicks, Air Force Institute of Technology
Sonia E. Leach, Air Force Institute of Technology

Abstract: Many organizations have established policies authorizing a "green" cost premium to fund sustainable design. In order to determine whether or not this practice is supported, we collected construction, cost, and utility data on a sample of 160 LEED certified buildings. Using simple correlation and descriptive statistics to analyze the resulting database, we found operating costs in LEED certified buildings were $0.70 per square foot less than non-LEED buildings, energy costs were 31% lower, and cost premiums ranged from 2.5 to 9.4% with a mean of 4.1%. Correlation analysis suggests there are very few statistically significant correlations among the design variables.

Keywords: Leadership in Energy and Environmental Design (LEED), Sustainability, Sustainable Design, Facility Construction, Green Cost Premiums, Engineering Economics

EMJ Focus Areas: Economics of Engineering, Innovation, Strategic Management

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Engineering Management Journal 2012.24:50-62.

As sustainability concerns continue to evolve, many countries have enacted various initiatives to improve building efficiencies. In response, many organizations have provided increasing attention to the concept of sustainable design—a philosophy recognizing that humanity must ensure, "…that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). In order to facilitate sustainable design, a tool that has captured the attention of both the public and private sectors is the Leadership in Energy and Environmental Design (LEED) program. Although there have been studies by consultants in the civil sector, individual building audits by universities, and energy studies by federal agencies (e.g., Kats et al., 2003; Stegal, 2004; Diamond et al., 2007), it does not appear as though a comprehensive study has been conducted regarding the cost effectiveness of LEED; therefore, our primary goal was to determine whether or not there is statistical support for policies and initiatives encouraging LEED certification for new construction and the associated cost premiums. A secondary goal was to determine whether or not there are any trends or correlations between variables that project managers and engineers can incorporate in their design efforts.

Background

The LEED® Rating System

In 1999, the United States Green Building Council (USGBC) released the LEED Green Building Rating System™ version 1.0. This was a pilot program that sought to create a system that the construction industry could use to achieve sustainable design goals. Using commissioning and evaluation, the USGBC awarded credits for incorporating sustainable design features into the building site, energy efficiency, material use, indoor environmental quality (IEQ), and water. Depending on the number of credits earned, a building could achieve a Bronze, Silver, Gold, or Platinum certification level (USGBC, 1999).

In 2001, the USGBC developed and released the LEED™ Rating System version 2.0. Based on feedback from the pilot program, the USGBC changed some of the credits, increased the number of credits, and replaced the Bronze certification level with a Certified level. Water related credits were changed to account for 5 of the 69 possible points, and Energy credits were changed to account for 17 possible points. Credits associated with water conservation were based on reductions compared to the plumbing fixture requirements of the Energy Policy Act (EPAct) of 1992 baseline. Energy efficiency credits were related to annual energy cost reductions in comparison with the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1 standard; successfully achieving those credits required the submission of a whole-building energy simulation to prove the designed levels of efficiency. Of the 17 energy credits and 69 available points, 10 credits were related to energy efficiency (USGBC, 2001). The USGBC continued to refine and expand LEED, and the next major change created new criteria for specific categories of buildings. For the purposes of this article, the rating system associated with new construction will be discussed.

The USGBC released the LEED™ Green Building Rating System for New Construction & Major Renovations (LEED®-NC) Version 2.1 in 2002. It kept the same technical standards for credit comparison and contained only minor changes to the credits associated with certification; the points required to achieve each certified level, shown in Exhibit 1, also remained the same. In 2005, the USGBC released the most recent changes to its rating system. Other than breaking out new construction categories, this change included removing existing buildings from the new construction category and updating the energy efficiency standard to the latest ASHRAE 90.1 standard (USGBC, 2005). Because the rating system had evolved since it was initially selected as their standard, the Government Services Agency (GSA) asked the Pacific Northwest National Laboratory (PNNL) to determine if the LEED® rating system was still the best approach for federal agencies. In their PNNL study, Fowler

Refereed Research Manuscript. Accepted by Special Issue Editors Gandhi and Merino.

and Rauch (2006) concluded that, although there were other sustainable design tools available, the LEED® rating system was the most favorable to ensure the federal agencies met their legal requirements. Finally in 2009, the USGBC released LEED 2009 for New Construction and Major Renovations Rating System. While certification levels remained the same, certification is now based on a 100-point credit scale, and the number of points required to achieve each level has changed; however, the basic construct and percent each area contributes in total points remains unchanged and similar, respectively. We believe engineering managers can use the data from the previous rating system to identify effective ways to maximize the efficiencies of current designs.

Exhibit 1. Points Required per LEED Level

Points Required Per Level LEED® - NC 2.0, 2.1, and 2.2				
	Certified	Silver	Gold	Platinum
Minimum	26	33	39	52
Maximum	32	38	51	69

Source: USGBC (2001, 2002, 2005)

Sustainability Cost Analysis

A number of studies have attempted to quantify the costs and benefits of sustainable design. Kats et al. (2003) provided a report for the state of California which is the most often cited study about costs and benefits associated with sustainable design. In their report, they calculated the net present value (NPV) of the resulting benefits shown in Exhibit 2. Their calculations were based on Microsoft Excel's standard NPV formula as shown in Equation 1,

$$NPV = \sum_{i=1}^{n} \frac{values_i}{(1+rate)^i} \quad (1)$$

where *rate* is the interest rate per time period, *n* is the number of time periods, *values* is the annual financial benefit, and *i* is year in which the benefit occurs.

It is difficult to determine all the details involved in their calculations, but the authors made some noteworthy assumptions. First, they assumed that inflation affects the value of costs and benefits similarly and, as a result, did not include inflation effects. Second, in 2003, the California Energy Commission directed that all state cost analyses use a real discount rate of 5%. Accordingly, Kats et al. (2003) used a 5% discount rate in their study; however, in their follow-on study of green schools, they used a 7% discount rate, adding 2% for assumed inflation (Kats et al., 2005). Based on this information, is reasonable to assume that the Kats et al. (2003, 2005) used a Minimum Acceptable Rate of Return (MARR) of 5%. Third, the authors chose a 20-year payback period as a subjective estimate of the usable life of each project's sustainable design investment. Four, the authors did not include any annual savings gained from federal, state, or municipal tax breaks associated with the incorporation of sustainable design techniques, which likely underestimates the NPV in locations that offer such incentives. Finally, since the context of their studies was in the public sector realm, Kats et al. (2003, 2005) conducted before tax analysis (not after tax).

Exhibit 2. Financial Benefits of Green Buildings

Net Present Value (NPV) over 20 Years	
Category	NPV per ft2
Energy	$5.79
Emissions	$1.18
Water	$0.51
Waste	$0.03
Commissioning	$8.47
Productivity and Health (Certified/Silver)	$36.89
Productivity and Health (Gold/Platinum)	$55.33
Cost Premium for Green Construction	($4.00)
NPV (Certified/Silver)	$48.87
NPV (Gold/Platinum)	$67.31

Source: Kats et al. (2003)

When grouping LEED certification into two groups (Certified/Silver and Gold/Platinum), Kats et al. (2003) found that productivity and health benefits accounted for about 70 and 82% of the respective NPV. Utility savings represented about 12 and 9% of the net present value, respectively; it is noteworthy that these savings alone were greater than the cost premium. While all 33 buildings included in the study were designed to LEED standards, only 5 of the buildings actually achieved LEED certification (Kats et al., 2003; Certified Project List, 2007). Kats et al. (2005) conducted a separate study on sustainable design in schools. The results were similar, but the benefits of increased worker productivity were replaced by increased student learning as a result of better daylighting.

Other Related Research

In other research, Lee et al. (2000) studied three existing buildings in Portland and concluded that the majority of the benefits were associated with increases in worker productivity. Similarly, the Department of Energy (DOE) found that utility savings from using energy efficient designs accounted for only about 12% of the total savings, while emissions accounted for 4% of the savings (DOE, 2003). They concluded that the majority of the benefits, almost 75%, come from incorporating design strategies that minimize costs associated with personnel turnover and the work area layout. Weber and Kalidas (2004) conducted a cost-benefit analysis for incorporating sustainable design elements into a college residence hall and concluded that the NPV of incorporating sustainable design exceeded the costs and was likely in the millions of dollars.

Kats et al. (2003) also reported that cost premiums tend to increase as the level of LEED certification increases as shown in Exhibit 3. Similarly, Lee et al. (2000) estimated that building costs would increase about 2% to achieve the LEED Certified level for the buildings in their study. In other work, Steven Winters Associates, Inc. (2004), found that cost premiums varied from -0.4% (i.e., a savings) for the Certified estimate to 8.1% premium for the Gold estimate. Stegal (2004) analyzed the costs of constructing a new residence hall and reported the cost premium for LEED to be between 1 and 2.8%. He also found that the building was about

20% more energy efficient than a building built to code; however, the energy efficiency was 6-12% worse than similar buildings that did not seek LEED certification but incorporated energy recovery systems.

Exhibit 3. Cost Premiums with Green Buildings

Certification Level	Average Cost Premium
Certified	0.66%
Silver	2.11%
Gold	1.82%
Platinum	6.50%
Average	1.85%

Source: Kats et al. (2003)

Matthiessen and Morris (2004) completed a credit-by-credit cost analysis of 138 buildings which included 45 LEED-seeking structures and 93 buildings not designed to LEED standards. They found cost premiums similar to those of Kats et al. (2003), varying from 1 to 10.3% as certification level increased; however, they also found that the costs of both LEED and non-LEED designed buildings varied significantly and that the cost variation of LEED buildings was within the cost variation of non-LEED buildings. Put more specifically, LEED certified buildings often cost less than non-LEED certified buildings. Matthiessen and Morris (2007) repeated their analysis with 221 buildings, of which 83 were designed to achieve LEED certification, and found the results to be similar to their previous study.

Many of these studies cited large benefits resulting from productivity increases, and a number included values for environmental externalities associated with energy production (e.g., Lee et al., 2000; Kats et al., 2003; Weber and Kalidas, 2004). Examining these areas more closely, Fisk (2000, 2002) and Milton et al. (2000) reported an increase in worker productivity as a result of decreased sickness due to improved indoor environmental quality. While these studies connect worker productivity and improved IEQ, they do not suggest that the effects associated with LEED certification are any greater than those associated with new construction built to current code. The 2005 Building Design Council annual report on the green building movement appears to suggest the same thing. Despite these efforts, there is no scientific evidence proving definitively that green buildings, whether LEED or otherwise, are in fact "healthier" for occupants, or that they do indeed make workers (in offices or factories) and children (in schools) more productive (Cassidy et al., 2005).

The studies mentioned above also included the social and environmental impacts of energy generation. This is typically accomplished through contingent valuation studies to measure the value of items that have no market by which one could base the valuation (Boyle, 2003). Air pollution has been linked to both poor respiratory health and poor visibility. Loehman et al. (1984, 1994) studied how much value residents of the San Francisco Bay area placed on air quality by determining their willingness-to-pay for better visibility and fewer unhealthy air quality days. Similarly, Farber and Rambaldi (1993) estimated the willingness-to-pay of outdoor exercisers in New Orleans. Rozen (2004) suggests that differences in personal preferences, such as willingness-to-pay values, may not be transferable across different populations; however, when applied to a local or national population, willingness-to-pay estimations can help determine a value for the externalities associated with location-specific project benefits.

Methodology

For our study, we focused on LEED-NC certified buildings. Of the 739 certified buildings listed on the USGBC's website as of August 31, 2007, 714 were certified under Version 2.0 or Version 2.1; therefore, we only included buildings that were certified under these versions. Unfortunately, we were not able to obtain data on every building since the USGBC allows owners to keep building utility and construction data confidential; therefore, we initially relied on three organizations maintaining large databases of LEED certified building case studies. The USGBC database contained 81 projects (Certified Project List, 2007); the DOE's Energy Efficiency and Renewable Energy (EERE) database listed 40 buildings (Building Database, 2007); and the BuildingGreen.com database consisted of 87 LEED case studies (Projects, 2007). Although some of these case studies lacked one or more of the required variables, there was sufficient overlap to determine missing information. Only those projects listing the year of completion, total construction cost (including soft costs and fees), square footage, and LEED certification scorecard were included in the study.

After combining the three sources and eliminating any duplication, we compared the sample projects to the population by both state and certification level (but not both together) to determine which states needed to be further researched and which certification levels needed more cases. To fill in the gaps, we identified a substantial number of new buildings by using the USGBC Certified Project List (2007) and searching the Internet. Construction and utility data were gathered from regional green building, local government, architectural firm, engineering company, and university building program website case studies. The required variables were often completed by comparing multiple sites along with using local newspaper and trade journal articles. Each building that was entered into the database had at least one online data source. The final database consisted of 160 LEED-NC v2.0 or v2.1 certified buildings. It is relatively representative of the population by certification (Exhibit 4) and location (Exhibit 5).

Exhibit 4. Comparison by Certification Level

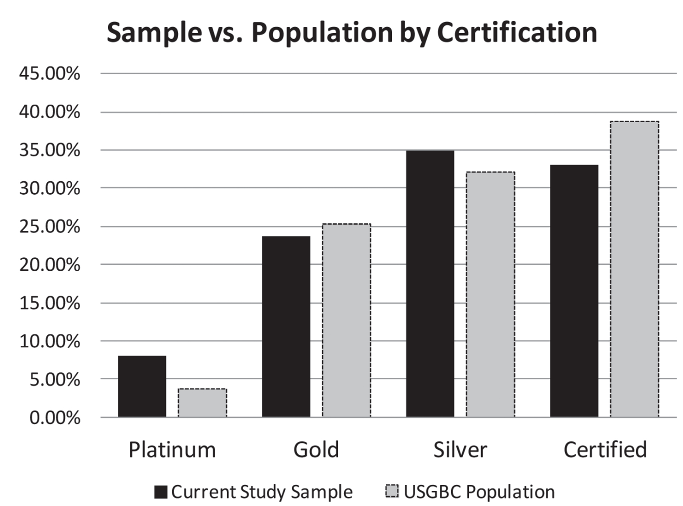
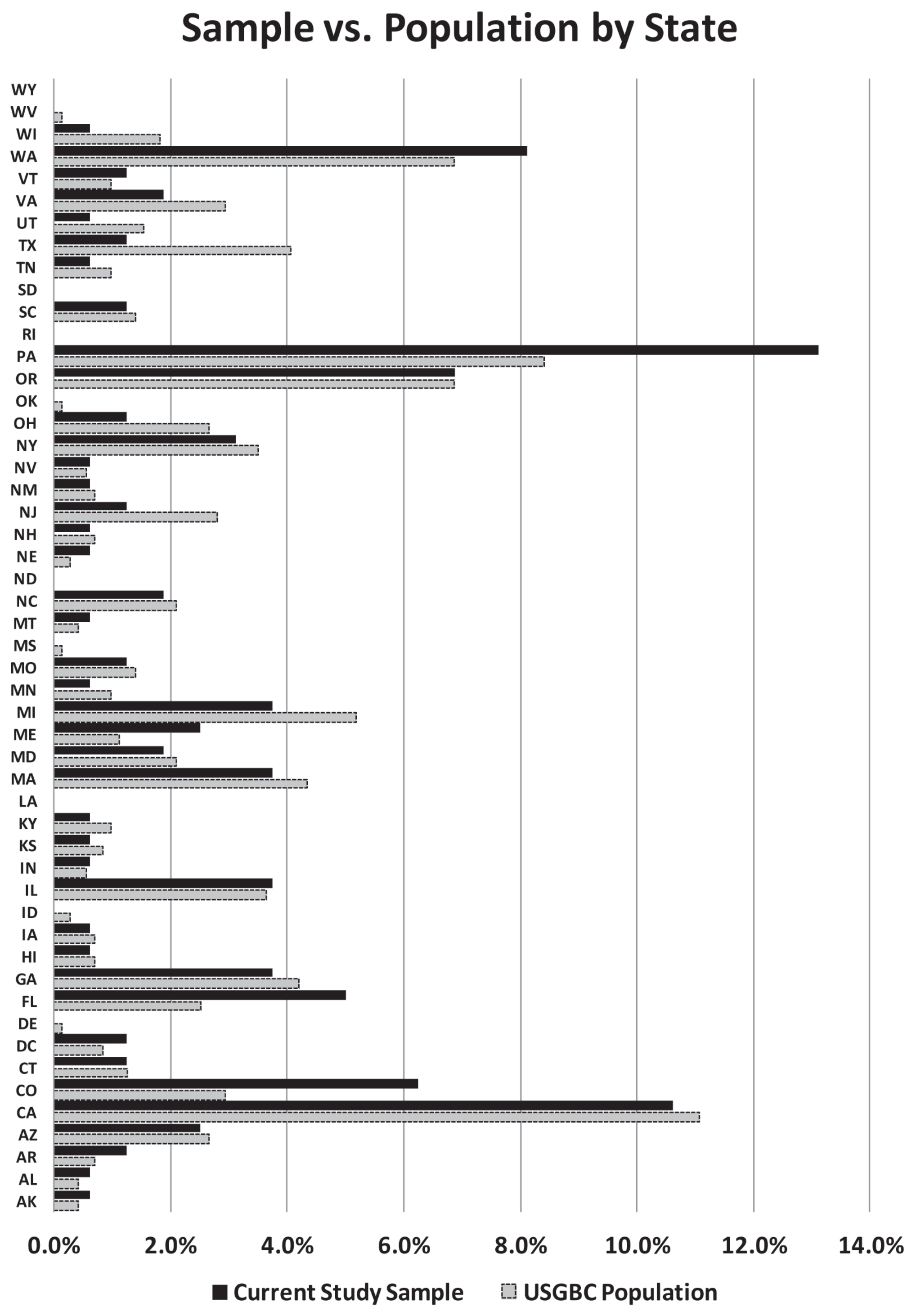


Exhibit 5. Comparison by Location



While not required for a building to be included in our study, additional variables were also gathered. Any information pertaining to water or energy consumption or savings, the owner, and the location was also recorded. Furthermore, all cited renewable energy facts, utility cost savings, green construction costs, and sustainable design tax benefits were captured. If case studies described utility consumption or savings resulting from post-occupancy monitoring, the original LEED certification data was used. This rational is based on the fact that these changes were the result of further financial investment that was not captured in the collected data.

The large number of sources required to collect the building data resulted in a database of variables in dollar values ranging over several years. The majority of the buildings in the database were completed in 2003 and 2004. Between those two years, however, the electricity and natural gas values were only available for 2003; therefore, we selected 2003 as our baseline year and used a project's completion date to normalize cash flows to a single year. Utility variables were normalized into similar units, but renewable sources of energy posed a unique problem. Wherever possible, we used cited annual values, but many photovoltaic systems were only described with a kilowatt rating. To estimate annual potential photovoltaic electricity generation, we used location-specific solar calculators such as the National Renewable Energy Laboratory's "The PV Watt Photovoltaic Solar System Performance Calculator" (NREL Solar Calculator 2007). Finally, total cost and square footage were used to calculate a cost per square foot unless the only data available was a cost per square foot calculation. Square footage was also used to normalize water, energy, and green cost information into units per square foot. We used the LEED scorecard to verify, and sometimes to provide, the percent water reduction and percent energy reduction.

Since geographic location had an impact on the local cost of living and climate, we categorized each project by building type, regional location, and state commercial cost of electricity and natural gas. Since the EERE, USGBC, and BuildingGreen.com case studies shared the same building classification system, we adopted their building types. To capture regional differences, each project was assigned a regional identification based on the census regions used by the Energy Information Administration (EIA). For reduced ownership costs, we used utility savings as a proxy, which required us to approximate the commercial cost of electricity, natural gas, and water. The value of those savings originated from either the case study or calculations found by multiplying each utility's savings with its corresponding rate and summing the resulting water, electricity, and fuel savings.

Since productivity and externalities benefits do not impact the bottom line of either ownership costs or construction premiums, we did not include them in our study. Additionally, using the Lee et al. (2001) and Kats et al. (2003) emission-only externality values combined with the DOE (2003) annual savings average building size, we estimated the average per square foot annual emissions-only externality value to be only \$0.03 per square foot. Given the anticipated accuracy of the secondary data we gathered, we did not consider the value of externalities to be significant.

We considered the green premium (GP) to be the cost to incorporate green design and sustainable construction features and calculated it using Equation 2,

$$GP = IC/(TC - IC) \quad (2)$$

where IC is the incremental costs and TC is the total cost. Incremental costs included: LEED registration and certification fees; extra commissioning fees; and solar heating, geothermal, and PV systems beyond code requirements. We were able to identify some cost premiums in situations where the owner did not provide a value by using limited declared tax benefits. Federal, state, and municipal tax incentives were available for incorporating various sustainable design elements into construction projects. For example, the 2007 Oregon Business Energy Tax Credit stated, "The tax credit is 35% of the incremental (or addition) costs of making the project exceed energy code or standard industry practice." For buildings that cited these types of tax credits, the dollar amount given was used with the tax credit percent to calculate the original incremental costs; however, based on various assumptions we made, the green premium listed in the database is more than likely a low estimate of the costs associated with sustainable design for that building.

The final database contained over 60 columns of numeric and non-numeric data for each building. While all of this information was necessary for data organization, validation, or manipulation, we only included the variables shown in Exhibit 6 in our analysis. In addition to these quantitative variables, a series of qualitative variables were coded as dummy variables to allow them to be used in correlation analysis. The dummy variables were binary coded and represented five categories: region, owner, construction type, building type, and renewable energy generated. The region category included the West, Midwest, South, and Northeast Census regions. The owner category was split into government and commercial, the construction type was divided into new or renovation, and the renewable energy generated was either yes or no. Since commercial offices accounted for over 25% of the sample, the building type category was coded with the option for commercial office and other.

Exhibit 6. Key Variables of Interest

Floor Area, Total Construction Cost/SF
Water Reduction, Water Intensity, Water Intensity Savings, Water Rate, Value of Water Intensity Savings
Electricity Intensity, Electricity Intensity Savings, Commercial Electricity Rate, Value of Electricity Intensity Savings
Energy Reduction, Total Energy Intensity
Fuel Intensity, Fuel Intensity Savings, Commercial Natural Gas Rate, Value of Fuel Savings, Value of Fuel Intensity Savings
Renewable Energy Onsite, Renewable Energy Intensity
Utility Savings
Green Premium
LEED Points Earned

We used SPSS 15.0 for Windows to determine descriptive statistics and create a correlation matrix for the entire data set. The data did not lend itself to regression analysis because of numerous missing values and the variation of construction variables between buildings. Additionally, the literature review revealed no equations pertaining to energy reduction, water conservation, operating costs, or cost premiums that combined the gathered construction variables. Further compounding the problem, when more than five variables are studied together, the listwise sample size decreases tremendously. Finally, very few variables showed significant correlation.

Results

Organizations pursuing LEED certification for their facilities typically have specific goals. For our research, we focused on the notional goals listed below and analyzed the data to determine if the goals were achievable.

- Reduced ownership costs through utility cost savings
- Energy intensity reductions
- Water intensity reductions
- An increase in the total facility construction costs of no more than 2 percent

Descriptive statistics for variables addressing these goals are shown in Exhibit 7. Since the histograms for the respective variables tended to reflect positive skewness in the data, we considered the median values to be better representatives of the central tendency of the data than the mean values; therefore, the median values are included in the discussion.

Exhibit 7. Descriptive Statistics of Key Variables

	Utility Savings (2003$/SF)	Energy Reduction Percent	Electricity Intensity Savings (kWh/SF)	Fuel Intensity Savings (kBTU/SF)	Water Reduction Percent	Water Intensity Savings (Gal/SF)	Green Premium Percent	LEED Points Earned
N (valild)	93	160	79	66	160	83	47	160
N (missing)	67	0	81	94	0	77	113	0
Mean	0.7038	31.2	6.2572	16.0700	26.2	3.4830	0.0408	35.3
Std Error of Mean	0.1108	0.0124	0.9356	3.4840	0.01551	0.6660	0.0077	0.6150
Median	0.3950	30.0	3.8340	6.0800	30.0	1.3313	0.0265	34
Mode	-	30.0	0	0	30.0	0	0.0101	33
Std Deviation	1.0682	0.157	8.3155	28.3070	0.191	6.0678	0.0526	7.782
Variance	1.1410	0.025	69.1480	801.2780	0.036	36.8180	0.0030	60.564
Range	8.6072	80.0	57.2584	152.0000	90.0	32.8423	0.2727	34
Minimum	0	0.0	0	0	0..0	0	0.0011	26
Maximum	8.6072	80.0	57.2584	152.000	90.0	32.8423	0.2738	60
25th Percentile	0.2085	22.4	1.6343	0	20.0	0	0.0134	29
50th Percentile	0.3950	30.0	3.834	6.0800	30.0	1.3313	0.0265	34
75th Percentile	0.8083	40.2	8.0574	16.7400	30.0	3.3136	0.0392	39

The statistical analysis supports the premise that LEED-NC certified buildings will enjoy reduced operating costs, using utility cost savings as a proxy measure, over non-LEED buildings designed and built to code. Specifically, the mean savings was about $0.70 per square foot; however, the median value of the savings was $0.40 per square foot. The mean savings was near the 75th percentile value of $0.81 per square foot. Regarding energy conservation, the data also suggests that LEED-NC certified buildings incur an average of 31% lower energy costs than non-LEED buildings. Since the median value was at 30%, the data for this variable more closely represented a normal distribution. Contributing to the overall energy reduction were the median electricity intensity savings of 3.83 kWh per square foot and median fuel intensity savings of 6.08 kBtu per square foot. The 27% reduction (median value of 30 percent) in water usage is similar to the energy reduction. The mean water intensity savings of 3.5 gallons per square foot (median value of 1.33 gallons per square foot) suggests that LEED certification will contribute to water conservation efforts.

Unfortunately, only 29% of the buildings reported sufficient information to calculate a green cost premium. Additionally, the incomplete nature of the data may lead to calculated premiums that were lower than the actual premiums. Despite this weakness however, the data still presents insight into the expected cost increases for incorporating sustainable design features. The mean cost premium was 4.08%, which is greater than the 75th percentile value. This is an indication of strong positive skewness in the data. Of the 47 projects with calculated cost premiums, only 5 of them had values greater than 10% (maximum was 27.4%). Thus, the median value of 2.65% is a much better representation of the central tendency of the data. In terms of the LEED points being earned, it is interesting to note the mean value of 35 points (median value of 34) and the 75th percentile value of 39. This is an indication that a large majority of the projects included in our study appeared to seek the minimal certification levels (primarily either Certified or Silver). This may be due to the additional costs associated with pursuing Gold or Platinum certification, lack of a true systems perspective of the building, or a desire to meet only the minimum requirements.

Trends in LEED

The second part of our research compared our results to previous studies. While the literature made numerous claims and cited various trends, our analysis was limited to three issues: green premium variation with the number of LEED points earned, green premium variation over time, and cost per square foot variation with the number of LEED points earned. As others have shown and intuition would suggest, the green cost premium tends to increase as the number of LEED points earned increases. This is reflected in Exhibits 8 and 9, respectively, in which Kats et al. (2003) and Matthiessen and Morris (2004) reported the green premiums associated with each certification level.

Our results, shown in Exhibit 10, are very similar; however, our analysis suggests that the average value of the green premium for each certification level, which varies from 2.5 to 9.4%, is slightly larger than previous studies. Additionally, since the green premiums we calculated are likely to be incomplete due to the lack of thorough reporting of green and sustainable design feature costs, the values shown are likely to be smaller than the actual green premiums.

Although Kats et al. (2003) reported that green premiums have decreased over time, their data, as shown in Exhibit 11, suggests that there was no such trend. Our results, shown in Exhibit 12, are similar. Neither exhibit appears to reveal any trends; however, this could be due in part to the incomplete nature of the calculated green premium.

Finally, the overall cost per square foot for the buildings in our study support the Matthiessen and Morris (2004, 2007) conclusion that the cost of incorporating sustainable design principles produces no more variation than any other construction

Exhibit 8. Green Premium versus LEED Certification Level (Kats et al., 2003)

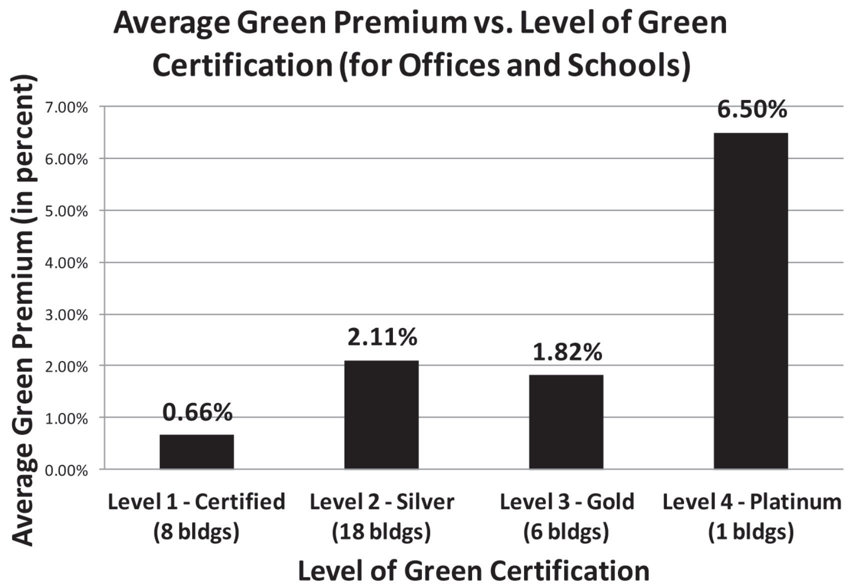


Exhibit 9. Green Premium versus LEED Certification Level (Matthiessen & Morris, 2004)

Location	Platinum	Gold	Silver
UCSB	7.8%	2.7%	1.0%
San Francisco	7.8%	2.7%	1.0%
Merced	10.3%	5.3%	3.7%
Denver	7.6%	2.8%	1.2%
Boston	8.8%	4.2%	2.6%
Houston	9.1%	6.3%	1.7%

Exhibit 10. Green Premium versus LEED Certification Level

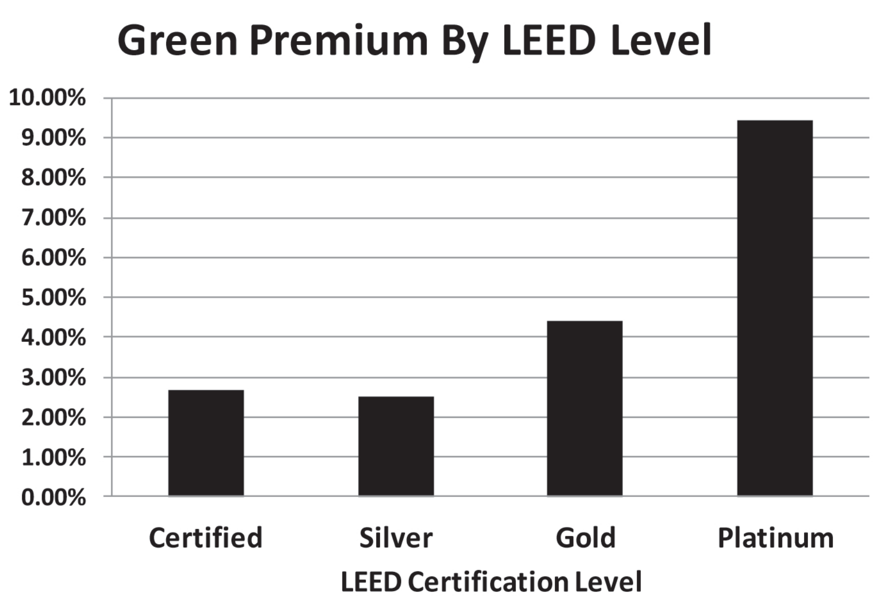


Exhibit 11. Green Premium versus Time (Kats et al., 2003)

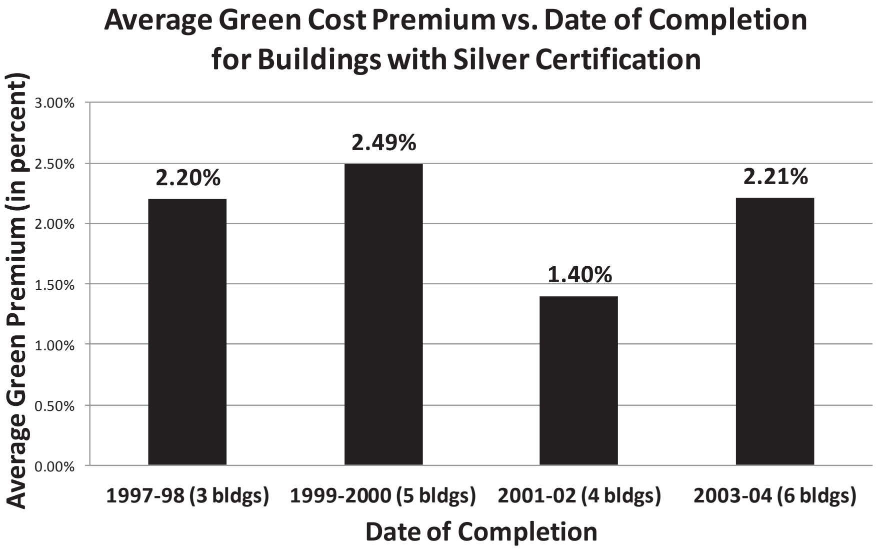
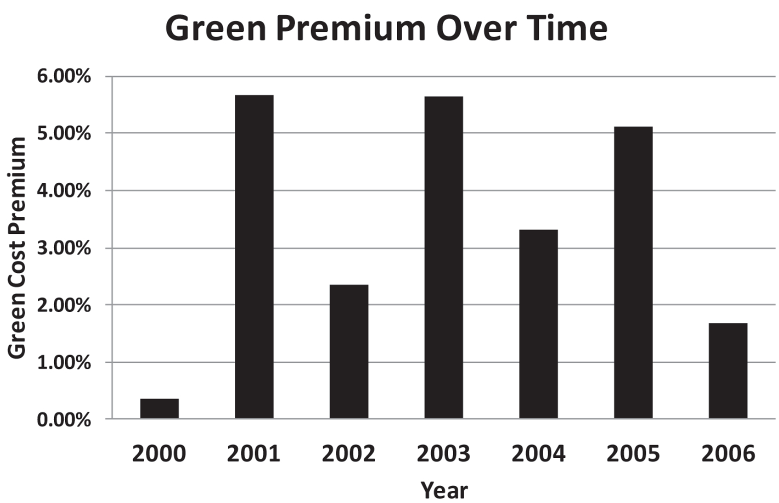


Exhibit 12. Green Premium versus Time



scope decision. To highlight the variation, we color-coded our data by LEED certification level. The resulting graph, shown in Exhibit 13, closely resembles a similar graph from Matthiessen and Morris (2004).

Additionally, since our data was exclusively from LEED-certified buildings, the cost per square foot for each LEED credit total was graphed to determine the variation among buildings achieving the same number of total credits. The graph is also color-coded to highlight the various LEED certification levels and is shown in Exhibit 14.

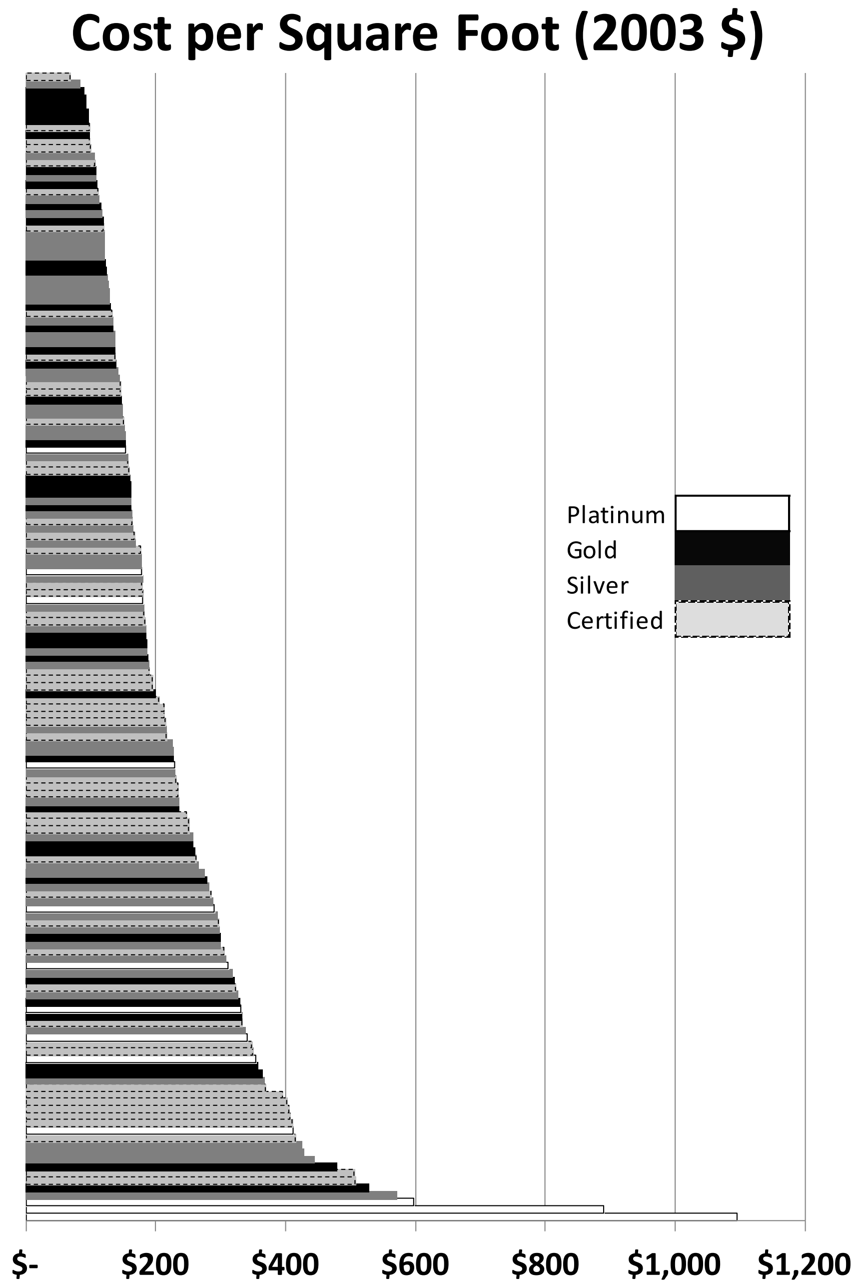
To examine other trends, we assumed that designers would know the anticipated cost per square foot, region, building type, construction type, use of onsite renewable energy generation, and LEED points being sought; therefore, these variables were compared to the rest of the database using a correlation matrix to identify trends of significance. Correlations were highlighted if statistically significant was at the 0.05 level or better, and if the correlation was moderate or greater using Patten's five-point scale. Patten (2005) associates moderate correlation with a Pearson's correlation coefficient of at least 0.5 and strong correlation with a Pearson's correlation coefficient of 0.75. The resulting correlation matrix revealed that the cost per square foot, region, building type, construction type, and use of onsite renewable energy generation were not statistically correlated with any of the variables gathered. The number of LEED points earned was moderately correlated with energy reduction. Although moderately correlated with the commercial cost of electricity, the Green Premium was not correlated with water reduction, energy reduction, utility cost savings, or LEED points earned.

Future Research

There is little doubt that our dependence on energy and clean water will continue to be a significant issue. These factors emphasize the importance of basing policy decisions on solid economic analysis. A large quantity of research to date has centered on new construction; however, there is a far greater quantity of old and inefficient existing structures. Future management study should focus less on the cost of new construction, which tends to be more efficient by design, and more on creating methods to incorporate sustainability into renovations. Rising utility costs, combined with limited capital for new construction in a depressed economy, should help fuel a market for renovating existing buildings.

While incorporating new technologies may seem to be an easy project scope decision, project managers need to be

Exhibit 13. Cost per Square Foot

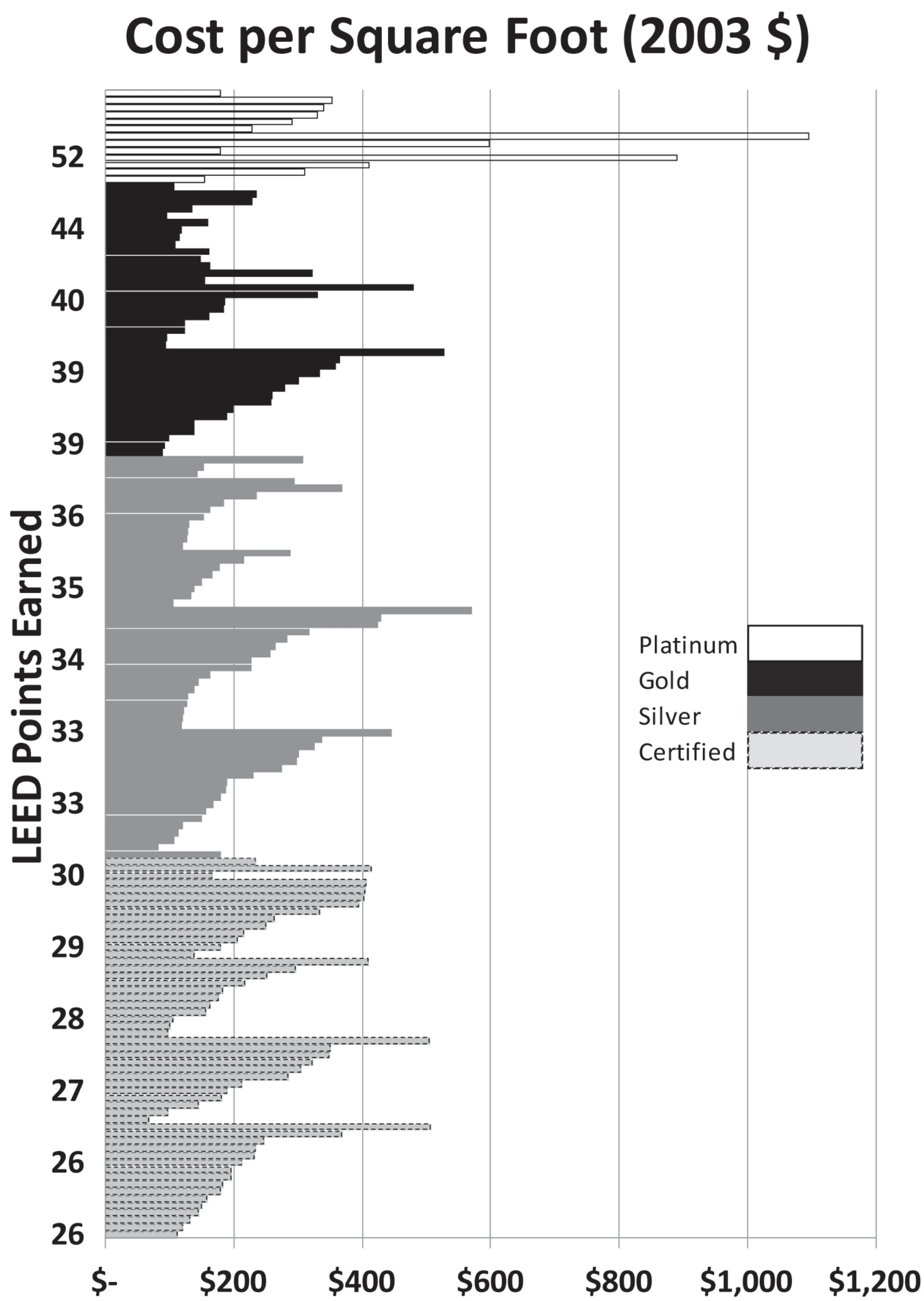


prepared to combine direct savings, externality values, and tax benefits into cost calculations in order to present realistic NPV calculations to owners. There is a noticeable gap in the existing literature pertaining to tax benefits and sustainable design. While it is a normal practice for project managers to perform MARR calculations using after tax data, raw tax data was difficult to attain, and as a result, our calculations were before tax. However, regional and local tax incentives and abatements appeared in projects throughout the country; therefore, engineering managers would decidedly benefit from future research on effective strategies to maximize tax abatements and incentives.

There is a multitude of economic research required to determine the benefits associated with externalities, and previous studies have attempted to place value on emissions based on the concept that air pollution increases bothersome visibility and respiratory problems to levels that increase death rates (e.g., Tolley et al., 1984; Loehman et al., 1984; Farber and Rambaldi, 1993). Yet most of these studies underestimate the effects because it is difficult to determine where the externalities intersect. For example, when does pollution begin to affect crop production, ecosystem life cycles, or even weather? Furthermore, public goods can intersect with private development in site improvement. For example, sustainable site considerations can help minimize the infrastructure required for storm water and contamination problems associated with runoff. Such improvements could create opportunities for states and municipalities to use revenue previously set aside for infrastructure for other public necessities or even construction tax abatements and incentives.

While ideas like incorporating bicycle racks and showers to earn LEED credits may seem inane at first glance, at some point increased physical activity for employees will likely lead to longer lives and reduced health care costs. Studies on the effects of indoor environmental quality (IEQ) suggest that workers will be sick less and thus able to work and reduce business inefficiency,

Exhibit 14. Cost per Square Foot per LEED Point Total



but what about the fact that they might live longer, too (Fisk, 2000; Milton et al., 2000). The low volatile organic compound (VOC) paints associated with better IEQ affect not just the employees occupying the new building, but the workers who apply them during construction, the customers who visit, and the environment in which they are disposed. In order to capture the multitude of externalities, new data must be gathered and new studies completed. The national benefits associated with these externalities are likely so large that discussing the benefits and costs associated with sustainable design without knowing their value is ill advised.

Yet, while some externality values may be generally transferable across the nation, many, as Rozen (2004) described, will not. As a result, every organization needs to research and develop local values for many of the externalities associated with their operations and thus better determine the complete value of the associated benefits. The dollar value of these benefits, as demonstrated by Weber and Kalidas (2004), will likely be millions of dollars, which would be more than ample justification for the added costs of sustainable design.

Conclusions

LEED certification is based on achieving a certain portion of a total number of possible credits, but the LEED criteria do not necessarily guarantee much with regard to sustainability. For example, 12 of the 160 certified buildings in this study received no credits for energy reduction. Of those 12 buildings, two achieved LEED Silver certification, and one incorporated ground source heat pumps without managing to achieve energy reduction credit. Additionally, 36 of the 160 buildings received no credits for water reduction, including 4 Gold and 14 Silver certified buildings. One of the basic Certified buildings neither incorporated renewable energy generation nor received credits for water or energy reduction. Furthermore, LEED certification requires registration, management and evaluation, which all amount to increased overhead cost just to secure the certification. In other words, if an organization definitely wants to ensure it meets certain sustainability goals, it will need to make additional design requirements beyond those required for LEED certification. Stated another way, LEED is not a one-size-fits-all program. Blindly following LEED criteria may not be the most cost effective or successful sustainable design approach, and managers need to dedicate careful thought and oversight to achieve sustainability decisions and goals through whole-building design strategies.

The LEED system also fails to ensure that environmental externalities are factored into decisions and instead focuses on the operating cost bottom line. For the energy efficiency credits, points are awarded based on energy cost reduction percentages in relation to the ASHRAE and local codes. This can result in some unfortunate situations. EIA's electricity emissions data supports the notion that burning coal tends to create more pollution than burning natural gas (2005). In situations where electricity is less expensive than natural gas though, a building's designers might achieve more energy reduction LEED credits by increasing the energy proportion gained from electricity and reducing the natural gas consumed. For example, Georgia has the 8th most expensive commercial natural gas, but their predominantly coal-generated electricity is only the 31st most expensive (EIA, 2006); however, the savings in utility costs associated with choosing electricity over gas that result in LEED credits are almost insignificant when compared with the total resulting externalities.

Furthermore, blindly choosing to seek LEED certification may not maximize return on investment. An LEED certification medallion on the building may carry certain marketing values related to company image, but there are structures that did not achieve LEED certification that enjoy greater utility efficiencies than certified structures (Stegal, 2004). Building modeling and simulation can help identify synergistic design elements, but engineers and project managers still need to utilize their basic economic, managerial, and engineering knowledge to ensure design selections are worth the investment. While many of the benefits of sustainable design are difficult to capture, Kats et al. (2003) has shown that often just the savings resulting from increased utility efficiency tend to outweigh the initial costs. Federal, state, and municipal tax benefits also offer additional opportunities to refine sustainable design scope decisions to maximize annual tax savings. Although the body of literature is currently lacking in the incorporation of tax savings in NPV calculations, it is reasonable to assume that tax benefits would positively impact the NPV of incorporating sustainable design options.

For managers to make accurate project decisions, we need more data. To generate the data recommended by Fowler et al. (2005) for studying sustainable design, it is imperative that project managers gather, organize, and maintain detailed lists of construction costs in a manner such that it can be accessed by higher level organizations. After getting the costs documented, the benefits need to be addressed. Modeling and simulation can provide estimated utility savings, and sustainable design programs like LEED encourage building commissioning, which has been shown to create direct cost savings. Mills (2004) studied 224 buildings and concluded that commissioning saved $1.24 a square foot in non-energy benefits like reduced change orders. Commissioning also documents many of the variables required above, and it properly prepares the owners to maintain the building by confirming and establishing a performance baseline for future comparison through metering. Furthermore, verifying meter results allows owners to realize simulation predicted savings by regularly managing and maintaining building subsystems.

Much effort has been focused on the initial cost of sustainable design, but after gathering the data for this study, it appears that there are simply too many variables in construction to create an accurate model for the cost of achieving LEED certification. Some have begun to investigate such a model (DOE 2003), but no published study has successfully documented the cost of constructing two nearly identical buildings, using the same basic design requirements, with one built to LEED certification or sustainable goals and one built to code. Lacking such a model, we can still draw worthwhile conclusions. Exhibits 13 and 14 depict very interesting variations in cost per square foot. More than one building that received Platinum LEED certification had a cost per square foot of less than half the cost per square foot of multiple structures that received only basic certification. It is reasonable to conclude that such cost variation was due in large part to a combination of the many scope decisions managers deal with throughout the design and construction process. Yet looking at the bottom line costs for choosing sustainable design, the median cost for incorporating green for the buildings in this study was only $5 per square foot. Compared to other scope decisions like roofing, paint, or carpet options, few choices have the opportunity to offer any kind of payback.

Our study offers the opportunity to make simple conclusions related to sustainable design, and our hope is that it will spur further research. We created the largest known, representative sample of LEED certified buildings. Like earlier efforts, the study was hindered by grossly incomplete data, but the data offers managers insight into incorporating sustainable design concepts into construction projects. Some of conclusions are similar to other studies, but far more was learned about the relationship between construction variables and sustainability through the compilation of the database and reflection on the results.

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About the Authors

David M. Nyikos received his MS in engineering management from AFIT and holds a BS in engineering sciences from the United States Air Force Academy. He is a pilot in the United States Air Force and is the commander of the 12th Operations Support Squadron at Joint Base San Antonio-Randolph. His research interests include the economics of sustainable design, innovation, and engineering management.

Alfred E. Thal, Jr., received his PhD in environmental engineering from the University of Oklahoma. He also holds an MS degree in engineering management from the Air Force Institute of Technology (AFIT) and a BS in civil engineering from Texas Tech University. He is an associate professor of engineering management in the Department of Systems and Engineering Management at AFIT. His research interests include sustainability, innovation, project management, and engineering and environmental management.

Michael J. Hicks received his PhD in economics from the University of Tennessee. He also holds an MA degree in economics from the University of Tennessee and a BA in economics from Virginia Military Institute. He is an associate professor of economics at Ball State University and is the Director of the Center for Business and Economic Research.

Sonia E. Leach received her PhD in industrial engineering from Arizona State University. She also holds an MS in operational research from AFIT and a BS in mathematics from The Pennsylvania State University. She is an associate professor and the associate director of OM/SCM programs in the Department of Information Systems and Operations Management at the University of Texas at Dallas. Her research interests include business analytics, mathematical modeling, and computer simulation.

Contact: Alfred E. Thal, Jr., Air Force Institute of Technology, Department of Systems and Engineering Management, AFIT/ENV (Bldg 640), 2950 Hobson Way, Wright-Patterson AFB, OH 45433-7765; phone: 937-255-3636, ext. 7401; fax: 937-656-4699; al.thal@afit.edu

Engineering Management Journal 2012.24:50-62.