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EFFECTS OF THE IMPLEMENTATION OF GREY WATER REUSE SYSTEMS ON CONSTRUCTION COST AND PROJECT SCHEDULE

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***Abstract:** One of the factors emphasized by Leadership in Energy and Environmental Design (LEED), a national consensus-based standard under the United States Green Building Council (USGBC) for developing sustainable or high performance buildings, is water efficiency. A LEED registered project can attain up to five points under water efficiency upon successful integration of various techniques to conserve water. Many techniques are available to conserve water and grey water reuse is one option considered by many LEED registered projects. In spite of widespread popularity, some of the sustainable techniques including grey water reuse, which is recommended by the USGBC and various agencies engaged in green building constructions, are not viable in many parts of the United States due to their effects on construction cost. Implementation of a grey water reuse system has a significant effect on the capital cost of a project. The increase in cost may be attributed to dual sanitary and grey water distribution piping which doubles construction piping costs. Disinfection treatment, filtration, overflow protection, grey water storage tanks, etc. also add to the cost of construction. Ninety percent of the projects claim that project schedule is not affected by the implementation of a grey water reuse system in a green building project. The factors which prevent the project team from implementing a grey water reuse system include capital cost, maintenance cost, local plumbing codes, local water conservation issues, complexity of the system, etc. LEED credits and the spirit of sustainability are the factors which have a positive effect on the design team's decision to implement a grey water reuse system.*

***Keywords:** LEED,USGBC,Grey water,Green Building*

I. INTRODUCTION

Buildings annually consume more than 30 percent of energy and 60 percent of electricity used in the United States (USGBC 2005). In North America the average commercial building generates up to 1.13 kilograms (2.5 pounds) of solid waste per .09 square meter (one square foot) of completed floor space (USGBC 2005). The construction industry and the built environment are major contributors towards the depletion of natural resources, including water (Augenbroe and Pearce 1998). The average American is responsible for 6804 kilograms (15,000 pounds) of carbon dioxide each year, which is greater than any other industrialized country in the world (Gore 2006). Forty percent of the total solid waste in the U.S. is the consequence of construction and demolition. All the activities involved during and after building construction alter the environment significantly (Lippiatt and Norris 1996). Utilizing current unsustainable building practices, the built environment is stealing away natural biologically diverse habitats and, in return, is burdening mankind with structures and developments devoid of life and biodiversity.

Reduced operational costs, increased worker productivity, and better indoor air quality are only a few of the added benefits of sustainable facilities. Since the inception of the United States Green Building Council (USGBC) in 1992, the green building construction industry has experienced immense growth in the U.S. There are approximately 5,000 registered projects and more than 600 certified projects under the Leadership in Energy and

Environmental Design (LEED) in the U. S. (USGBC 2007c). Studies of workers in green buildings show a 16 percent increase in productivity gains and reduced absenteeism (USGBC 2005).

II. Literature study:

Grey water reuse outside the U.S

In densely populated and developing countries, water reuse, in line with urban planning and development, has always been a necessity. In the developed global community, countries involved in active research and use of grey water reuse systems include Japan, USA, Germany, Canada, UK, Sweden and Australia.

A review of the current literature provides insight into the valuable experience of water conservation in developed as well as developing countries. The focus is placed on the treatment of grey water with ecotechnological methods. Some of the efficient waste water and grey water systems followed in developed countries like Sweden, Japan, Greece, Germany and the United Kingdom are exemplary and can be emulated elsewhere in the world.

Tokyo, Japan –

Tokyo is one of the cities which has promoted the reuse of waste water and grey water more than any other city in the world. As one of the most technologically advanced countries in the world, waste water treatment plants in Tokyo, Japan generated 10.8 X 1012 liters of water in 1996. The treated waste water is used for toilet flushing, train washing, dilution water for night (human feces), landscape irrigation .

Victoria, Australia –

Though the Australian authorities discouraged grey water recycling in the early 1990's, the prevailing drought conditions have prompted them to reconsider grey water reuse for non-potable use. A simple valve for diversion of laundry water for landscape irrigation was developed and received interim approval from the authorities (Anderson 1996).

Grey water reuse in the United States

"If water is life...water conservation and reuse must be our way of life" (Florida DEP 2006a). In the United States, around 1300 billion liters (340 billion gallons) of water are drawn from rivers, streams and reservoirs for residential, commercial and industrial uses (USGBC 2005). According to the USGBC, Americans extract 14000 billion liters (3700 billion gallons) of water more than they return to nature. The continued increase in population, coupled with the growth in demand placed on the fresh water supplies, has led to an ever increasing dependency of water reuse. Areas with limited water resources, such as the arid U.S. Southwest, already have well established water reclamation and reuse programs (Bastian 2006).

The emerging trends of green buildings and LEED certification are promoting many builders and owners to seek sustainable solutions in building construction. LEED provides 5 credits for water efficiency under LEED NC Version 2.1 and one of the recommended technologies is grey water reuse systems in residential as well as commercial construction (USGBC 2003). Currently, there are no federal regulations directly governing water reuse practices in the U.S. Water reuse regulations and guidelines have, however, been developed by many individual states. As of November 2002, 25 states had adopted regulations regarding the reuse of reclaimed water, 16 states had guidelines or design standards, and 9 states had no regulations or guidelines (EPA 2004). In states with no specific regulations or guidelines on water reclamation and reuse, programsmay still be permitted on a case-by-case basis (EPA 2004).

III. RESEARCH METHODOLOGY

An extensive internet search on existing green buildings with grey water reuse systems in the U.S. was done. The USGBC and LEED websites were used to locate registered and certified green buildings in the United States. Architects, general contactors and engineering firms were identified who were familiar with green building construction in the U.S. Case studies were done on certified as well as ongoing construction projects where grey water reuse systems were used. Reports published by United States Environmental Protection Agency and other state agencies were analyzed to get a list of states where grey water reuse systems were and were not permitted and to study various standards regarding recycled water use.

Research Survey

After receiving approval from the Institutional Review Board (IRB) at Texas A&M University, two questionnaires were prepared using online professional survey software provided by SurveyMonkey.com. These research surveys, which were designed for LEED registered and LEED certified projects, were pre-tested using people

familiar with green building construction.
The electronic links of the research surveys, along with a cover sheet describing the goal of this research, were sent to a group of building professionals mainly comprising of:

Architects ,General contractors ,Engineers ,Building owners ,Project managers ,Landscape architects ,Plumbing contractors ,LEED consultants.

Contact information of the professionals representing LEED registered and LEED certified projects was obtained from various sources including the LEED AP directory posted under the USGBC website (USGBC 2007c), the Office of Energy Efficiency and Renewable Energy under the Department of Energy (DOE) website (USDOE 2007) and general web searches on green building projects. From an extensive internet search, 26 LEED certified buildings were identified with grey water reuse systems in the United States out of which approximately 15 responded to the survey. It was difficult to assess the exact number of LEED registered projects with grey water reuse systems.
The data was collected from approximately 66 green building projects in the U.S. which were registered and certified under the LEED rating system. Due to privacy agreements, project information and names of the architect, builder, location, etc. were only shared with the graduate committee members at Texas A&M University.

Analytical methods

The characteristics of the data collected necessitated the use of the following analytical methods:

Bernoulli distribution

Any random variable that takes only two values, such as 0 and 1, is called a Bernoulli random variable. An experiment with a dichotomous outcome is called a Bernoulli trial (Tamhane and Dunlop 2000).

Binomial distribution

The experiments carried out for this research can be viewed as a series of independent and identically distributed (i.i.d.) Bernoulli trials where each outcome was a “YES” or “NO”. The total number of “YES” or “NO” responses is of more interest than the individual outcomes. If there is a fixed number n of trials that are independent and each trial has the same probability p of “YES”, then the sum of these i.i.d. Bernoulli random variables are referred to as a binomial random variable (Tamhane and Dunlop 2000).

Chi-square test

Chi-square is a non-parametric test used to evaluate statistically significant intersections of independent and dependent variables and understand the relationship between these variables if any (Conor-Linton 2007). It is concluded that there is a statistically significant relationship between the variables if the null hypothesis is rejected. In this study, the relationship between the factors and the implementation of grey water reuse were evaluated separately and hence a 2 x 2 contingency table was used.

Data coding and analysis

Since the experiment involved dichotomous outcomes, it is called a Bernoulli trial (Tamhane and Dunlop 2000). As an example, suppose in answering the research survey the project representative responded with “yes” or “no” when asked if they considered implementing a grey water reuse system, “1” or “0” were assigned while coding the data into a Microsoft Excel sheet. Similarly, “1” was assigned for “strongly agree” and “agree” and “0” was assigned for “strongly disagree” and “disagree” responses in the research survey. If the respondent selected “neutral”, it was not considered for the analysis.

IV. CONCLUSIONS

On 76 percent of the projects where grey water reuse systems were utilized or were being considered, capital cost of the project was affected by the implementation of a grey water reuse system. It is clear that implementation of grey water reuse systems has a significant effect on the capital cost of the project. The increase in cost may be attributed to dual sanitary and grey water distribution piping which doubles construction piping costs. Disinfection treatment, filtration, overflow protection, grey water storage tanks, etc. also add to the cost of construction. Ninety percent of the projects claim that project schedule is not affected by the implementation of grey water reuse systems in a green building project.
There are a multitude of factors which a project team considers before deciding on a particular technology or equipment for a construction project. The factors which were discussed in this study were capital cost, LEED credits, and complexity of the system, project schedule, maintenance cost, water conservation issues in the locality, tax incentives, and payback time of the system. While capital cost was found to be significant factor affecting the project team’s decision on the implementation of a grey water reuse system, LEED credits and complexity of the system were found as important factors by projects which implemented a grey water reuse system. The projects which did not implement grey water reuse systems did not feel that gaining LEED credits was more important in comparison to increased capital cost and they opted for other cost effective technologies in comparison to grey water reuse systems to conserve water. Many projects which considered using grey water reuse

systems were discouraged by the lack of proper plumbing codes in their state. Some of them took initiatives in seeking variances in the existing state codes to implement a grey water reuse system. Of the buildings which have successfully implemented grey water reuse systems and were studied for this research, the savings reaped from not using as much potable water were notable and there was less sewage to be treated.

In addition to the main factors studied in this research, there are additional factors which affect the project team's decision whether to implement a grey water reuse system or not. They are:
1) Plumbing codes: Even if a project team wants to implement a grey water reuse system, there are no plumbing codes in some states and cities which permit the usage of grey water. The states which approve grey water reuse systems were discussed earlier in this thesis. A project team's ability to include a grey water system currently lies in the hands of the local plumbing code authorities.

2) Cultural issues, mental block: A popular misconception among owners and clients is that grey water is not safe to reuse, coupled by the fact that its use is not approved by some state departments.

3) Lack of expertise, knowledge or previous experience: Lack of familiarity with grey water reuse systems adds to the difficulty in implementing this strategy in a project. Concern that grey water would need some chemical treatment, to some degree, to prevent storage of quantities of grey water from " going bad".

4) Other cost effective LEED points: Projects opt for other technologies which are cost effective in comparison to grey water reuse systems, like water efficient landscaping, storm water and rain water capturing, water efficient fixtures, etc. to save water and attain LEED credits.

5) Spirit of sustainability: In spite of many hurdles and factors that hinder project progress, some projects inspired by sustainable principles, and design opt for grey water reuse systems.

Recommendation for designers, contractors, owners and government agencies

From this study and the valuable opinions obtained from many architects, contractors and owners who participated, it is very clear that grey water reuse systems were definitely considered or are being considered as a possible strategy to conserve water and reduce waste water irrespective of location. However, lack of information on grey water reuse systems, lack of expertise, lack of proper codes for recycled water usage, etc. were some additional factors which prevented the project teams from implementing grey water reuse systems, apart from capital cost and complexity of the system. In order to overcome the lack of knowledge on grey water reuse and promote emerging water conservation techniques, federal and state agencies should make an attempt to create and practice uniform plumbing codes and unambiguous health codes. Educational pamphlets on water reuse and low risk of health hazards should be distributed in schools, health centers, utilities agencies, etc. to educate people about water reclamation and safety standards.
According to officials at the Inland Empire Utilities Agency, a water utilities agency which recycles and provides water for 7 cities in southern California, education about water reuse is very important. The newsletters and pamphlets published by this agency include information, answers to common questions, and common misconceptions regarding recycled water use. Projects using grey water should be promoted as demonstration sites by USGBC, state agencies, designers and builders to increase popularity and educate users about their benefits. It is also advised to model the system on an annual basis to determine the grey water volumes, storage capacity, etc. as the grey water volumes may not be consistent through out the year. Installing dual plumbing lines during the initial construction is a good idea to avoid substantial costs if the project is planning to implement a grey water reuse system in the future.

Recommendation for future research

There are some additional factors which were not taken into consideration while designing the research survey. Researchers in future are recommended to consider the following factors in addition to the ones considered by this study:
1) This study only focused on LEED projects in the U.S and it is recommended to include non-LEED building projects in the U.S. in future studies.

2) Local, state and national codes pertaining to water recycling, grey water and black water use should be considered as a factor.

Grey water reuse systems in the U.S have a great future especially in the areas where there are shortages of potable water. If given more importance and publicity by the federal and state agencies, more grey water systems could be incorporated into commercial, industrial and residential buildings. Engineering firms, federal and state agencies, utilities agencies, etc. should take initiative in publishing reports describing the advantages, water savings, energy savings and safety aspects of grey water systems to influence public acceptance, which is paramount for the growth and success of any system or technology in every day life.

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