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

A Thesis

by

JESLIN KADUVINAL VARGHESE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2007

Major Subject: Construction Management

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Approved by:

Chair of Committee,	Charles W. Graham
Committee members,	Richard Burt
	Seth Guikema
Head of Department,	Charles W. Graham

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ABSTRACT

Effects of the Implementation of Grey Water Reuse Systems on Construction Cost and Project Schedule. (August 2007)

Jeslin Kaduvinal Varghese, B-tech, Kerala University, India

Chair of Advisory Committee: Dr. Charles W. Graham

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 and project schedules. Even though a project could get one or multiple points upon successful implementation of a grey water reuse system and conserving potable water, the following factors may have a positive or negative effect on the design team's decision to implement a grey water reuse system: capital cost, maintenance cost, LEED credits, local plumbing codes, project schedule, local water conservation issues, complexity of the system, etc.

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.

DEDICATION

To

My dear friends

My sister and brother-in-law

My parents

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I would like to take this opportunity to express my sincere appreciation and gratitude to my advisory committee. I would like to thank Dr. Charles Graham for giving me an opportunity to work with him, for providing me with suggestions throughout the length of the study in spite of his busy schedule, and above all for being a wonderful mentor. I would like to thank Dr. Richard Burt for encouraging me to choose a topic related to sustainable construction, for helping me obtain accreditation in LEED and advising me to gain more knowledge in green building constructions. I express my sincere thanks to Dr. Guikema Seth for guiding me with his expertise and providing me with numerous insightful articles which I have used towards the literature sources for this research, not to mention the support and the encouragement he gave me throughout the process. I would like to thank the Department of Construction Science for giving me the opportunity to study at Texas A&M University. I thank my sweet friend Anne Willis for extending a hand of support whenever I had a problem, for encouraging me and boosting my morale, and for reading and editing my thesis in spite of being busy with eighty-five other things.

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INTRODUCTION

“You must be the change you wish to see in the world.”

Mahatma Gandhi

India’s “Father of the Nation”

Background

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. The time has come to act sensibly and reduce or the negative environmental impacts of the built environment by improving existing design, execution and operational practices.

The successful practice of sustainable design, coupled with the judicious use of natural resources, is a viable option to conserve and save the environment from further exploitation.

This thesis follows the style of the *Journal of Construction Engineering and Management.*

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).

United States Green Building Council

The U.S Green Building Council, founded in 1992, is part of the World Green Building Council (WGBC) and is one among many organizations in the country which works towards sustainable design and practice. However, what marks the USGBC apart from others is that it is a national non-profit organization with more than 7,500 member organizations and 75 chapters nationwide (USGBC 2007c). The core purpose of USGBC is to transform the way buildings are designed, built and operated and make them more socially and environmentally responsible (USGBC 2007c). Other countries that are part of the WGBC include Australia, Britain, China, India, Japan, Mexico, Spain, and United Arab Emirates.

Leadership in Energy and Environmental Design

The Leadership in Energy and Environmental Design (LEED) rating system is a set of consensus-based national standards developed by the USGBC for developing high-performance sustainable buildings or green buildings (USGBC 2003). The LEED rating system can be applied for every building type and phase of a building lifecycle, namely:

- New commercial construction and major renovation projects
- Existing building operations and maintenance

- Commercial interior projects
- Core and shell development projects
- Homes
- Neighborhood developments
- Schools

The LEED rating system is divided into 6 divisions, which are then further sub-divided into 7 prerequisites and 69 credits. The 6 categories in the LEED rating system are:

- Sustainable sites development
- Water efficiency
- Energy and atmosphere
- Material resources
- Indoor air quality
- Innovation and design

The LEED reference guide, version 2.1, provides information on all the 69 credits, including credit intent, requirements, submittals, strategies, etc. In order to get certified a project needs to get registered under the LEED website, meet all the prerequisites and attain at least 26 points under the above mentioned divisions. The level of certification is as follows:

- Platinum: 52-69 points
- Gold: 39-51 points
- Silver: 33-38 points
- Certified: 26-32 points

The sustainable design concepts, guidelines and practices prescribed in the LEED reference guide and related literature ensure that every building certified under LEED is environmentally friendly, socially responsible, profitable and a healthy environment to work or live in. The advantages of including sustainable practices into construction of a building are:

- Lower energy costs by using energy efficient lamps and fixtures, monitoring usage, and using occupancy sensors to control lighting fixtures, heating and cooling equipment (Gottfried 1996).

- Lower water costs by monitoring consumption, using water efficient fixtures and faucets, reusing storm water and grey water, and making use of indigenous plants for landscaping which require less water (Gottfried 1996).
- Lower materials costs through the careful purchase and reuse of resources and materials and by using materials that are locally available (Gottfried 1996).
- Increased productivity of workers, reduced employee absenteeism, and fewer employee health problems resulting from poor indoor air quality (Gottfried 1996).

Water efficiency and conservation

One of the natural resources available in nature is water; however, it is not readily available for millions of people across the globe for domestic use. The amount of water available for use on the planet is finite (Athens and Ferguson 1996) and out of the available water, only 3 percent is potable, 2 percent of which is frozen in glaciers and polar ice caps, which leaves only 1 percent as useable water (NASA 2007). For a sustainable urban future the citizens of a country must progress towards the goal of efficient and appropriate water reuse (Dixon et al. 1999). Some of the major considerations while designing and building sustainably are conservation and thoughtful use of land, materials, methods, water, natural resources and energy.

According to the USGBC, approximately 1300 billion liters (340 billion gallons) of fresh water are withdrawn daily from rivers, streams and reservoirs to support residential, commercial, industrial, agricultural and recreational activities in the United States. This is approximately equal to one fourth of the nation's renewable fresh water supply (USGBC 2005). Nine billion liters (five billion gallons) of potable water are used to flush toilets daily (USGBC 2003). On an annual basis, the water deficit in the United States is estimated at approximately 14000 billion liters (3700 billion gallons) (USGBC 2003). Water efficiency measures in commercial, residential and industrial buildings can easily reduce water usage up to 30 percent (USGBC 2005). At present, there are a plethora of options to conserve water, but not all are practiced due to various reasons.

LEED and water efficiency

One of the 6 categories under which LEED evaluates a registered green building is water efficiency (WE). A LEED registered project can attain up to 5 points under water efficiency credits upon successful integration of various techniques to conserve water. WE is one of two sections which does not have any prerequisites. Detailed information on intent, requirement, strategies, synergies and trade-offs, and submittals can be found in the LEED reference guide, version 2.1. Following are the WE credits under LEED, version 2.1:

1. WE credit 1.1 Water efficient landscaping – 50% reduction
2. WE credit 1.2 Water efficient landscaping – No potable use or no irrigation
3. WE credit 2 Innovative wastewater technologies
4. WE credit 3.1 Water use reduction 20% reduction
5. WE credit 3.2 Water use reduction 30% reduction

For obtaining points under credit 3.1 and 3.2, projects have to employ strategies that in total use 20 or 30 percent less water than the water use baseline calculated for the building after meeting the fixture performance requirements of the Energy Policy Act of 1992 (EPACT) (USGBC 2003). The fixtures included in EPACT of 1992 are water closets, shower heads, faucets, urinals, etc. which will save the U.S. an estimated 25 billion liters (6.5 billion gallons) of water per day (USGBC 2003). Approximately 9 billion liters (five billion gallons) of water are being used for toilet flushing alone (USGBC 2003). The LEED reference guide emphasizes a plethora of options to conserve water in commercial as well as residential buildings to exceed the EPACT standards.

Suggested water conservation practices

1. **Water harvesting and rain harvesting**

The collection of runoff from the earth's surface, paved surfaces and other surfaces, and storing it for future use, is called water harvesting. Harvested water can include storm water, surface run off, water from swales, cooling towers, air conditioning systems and other drainage structures, which is directed to a catchment basin or detention pond (Athens and Ferguson 1996). The harvested water can be used for irrigation, thus conserving potable water from being used.

2. **Xeriscaping or water efficient landscaping**

Installation of indigenous landscaping that does not require permanent irrigation systems eliminates the usage of potable water for irrigation (USGBC 2005). In addition to offering biological diversity to a region and preserving the behavior of regional landscaping, native plants or well adapted species need less or no water in comparison to non-native varieties, thus conserving water (Athens and Ferguson 1996).

3. **Use of water-efficient fixtures**

Use of water efficient fixtures, faucets, waterless or low flow urinals, dual flush tanks, composting toilets, etc. save tremendous amounts of water in a building facility (USGBC 2003).

4. **Grey water reuse systems or water reclamation**

Potable water is being used for many purposes that do not actually require high quality water such as toilet and urinal flushing, irrigation, cleaning vehicles, etc. (USGBC 2005). One of the strategies emphasized by the LEED rating system under USGBC to conserve water is grey water reuse. Dual plumbing within a building facilitates the collection of grey water from sinks, showers and other sources which can be reused for toilet and urinal flushing, irrigation, etc. (Athens and Ferguson 1996). The successful implementation of a grey water reuse system helps a building conserve potable water to a very good extent and it also adds one or more points towards the project's LEED certification. However, there are many factors which affect the project team's decision whether or not to implement it. Regulations and guidelines vary considerably from state to state (EPA 2004). Dual sanitary and grey water distribution piping doubles construction piping costs and disinfection treatment, filtration, overflow protection add to the cost of construction, operation and maintenance (USGBC 2005).

5. **Grey water and rainwater in combination**

Rainwater reuse has a long, world-wide history, however, the use of rainwater in combination with grey water has not been researched, although it seems to offer much potential in terms of quality and quantity (Dixon et al. 1999).

Problem statement

The goal of this research was to analyze the effects of the implementation of grey water reuse systems on construction project schedules and the cost of green building projects in the U.S.

Sub problems

1. To analyze the effects of capital cost, maintenance cost, payback time, project schedule, water conservation issues, tax incentives, LEED credits and complexity of the system on the implementation of grey water reuse systems in the U.S.
2. To study and analyze existing green buildings with grey water reuse systems registered or certified with the LEED program under the USGBC in the United States.

Assumptions

1. The overall research and data analysis approach adopted for the study was assumed to be adequate to analyze the effects of the implementation of grey water reuse systems on construction project schedule and cost of commercial and industrial construction projects.
2. The owner, architects, and general contractors played an important role on decisions pertaining to the project and in meeting the targeted LEED rating.

List of definitions

Sustainability: "Meeting the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development 1987)."

Grey water: Wastewater from bathtubs, showers, sinks, washing machines, and dishwashers which contains little or no pathogens and 90 percent less nitrogen than black water (toilet water) (Christensen 2006). International Plumbing Code (IPC) defines grey water in its Appendix C, titled "Grey water recycling systems" as "waste discharged from lavatories, bathtubs, showers, clothes washers, and laundry sinks."

LEED: Leadership in Energy and Environmental Design. The LEED Green Building Rating System is the nationally accepted benchmark for the design, construction, and operation of high performance green buildings (USGBC 2007b).

Black water (toilet waste): A term used to describe water containing fecal matter and urine or both (Wikipedia 2007a). It is the waste water from toilets and kitchen sinks that contains organic materials (USGBC 2003).

Evapotranspiration: The loss of water by evaporation and transpiration; evaporation from the soil and transpiration from plants (USGBC 2003).

Xeriscape: The practice of “dry landscape” designs where native plant species that are adapted to local climate are used to conserve water (USGBC 2003).

LEED registered projects: Project registration is the first step to get any building certified under the LEED rating system. Any project which pays the registration fees and establishes a contact and account with USGBC is called a LEED registered project. A LEED registered project also has access to LEED online and LEED credit interpretation database (USGBC 2007c).

Credit Interpretation Requests (CIR): The USGBC has established a review process for registered project inquiries, called credit interpretation requests (CIRs), to help project teams that may encounter problems applying prerequisites and credits. A registered project should refer the reference guide and previous credit interpretation rulings if they encounter any problem. If the question is not answered sufficiently by an existing CIR, a registered project can seek solution by submitting a CIR through LEED online. Each CIR costs $220 (USGBC 2007a).

LEED certified projects: Registered projects which meet all the 9 prerequisites and a minimum of 26 points get certified under the LEED rating system. The various levels of certification include Platinum (52-69 points), Gold (39-51), Silver (33-38), and Certified (26-32).

Limitations and delimitations

The research investigated the effects of the implementation of grey water reuse systems on construction project schedules and the costs. The research also studied the influence of LEED credits, maintenance cost, tax incentives, water conservation issues, local codes, capital cost and complexity of the system on the implementation of grey water reuse systems in the U.S. The study only focused on registered and certified projects with the LEED program under the USGBC. Documented studies dealing with grey water reuse systems around the world supplied the groundwork for this feasibility analysis of grey water reuse systems.

Expected benefits of the study

The results of the study will benefit contractors, owners and government agencies that are interested in sustainable constructions and in the implementation of grey water reuse systems. Study on existing grey water reuse systems in the U.S. and other developed countries will be conducive to contractors and owners who are planning to implement a grey water reuse system in their project. The effects of the implementation of grey water reuse systems on project schedules and the costs will benefit construction managers working with contractors and owners to understand the various implications involved if any. In general, following are the benefits of the study:

1. To identify the effects of implementation of grey water reuse systems on the schedules and budgets of green building projects in the United States.
2. To find the effects of capital costs, maintenance costs, LEED credits, complexity of the system, water conservation issues, etc. on the implementation of grey water reuse systems in the United States.

LITERATURE REVIEW

The literature review is divided into two sections. The first section describes the characteristics of grey water and its applications in various countries and also in the United States. The second section consists of brief discussions on conceptual planning, feasibility analysis and the project team's role in achieving project objectives.

Characteristics of grey water

Grey water is wastewater from bathtubs, showers, sinks, washing machines, and dishwashers. It contains little or no pathogens, and ninety percent less nitrogen than black water (toilet waste) (Christensen 2006). Because of this, it does not require the same treatment process. By designing plumbing systems to separate grey from black water, grey water can be recycled for irrigation, toilets, and exterior washing, resulting in water conservation. When planned into new residential and commercial construction, the building unit's wastewater treatment system can be significantly reduced, resulting in cost and space savings (PATH 2006). The amount of grey water produced in a household or commercial construction can greatly vary depending upon the number of occupants and size of the facility.

The composition of grey water greatly varies on the type of building and usage of chemicals for washing, laundry, etc. In general, it contains often high concentrations of easily degradable organic material, i.e. fat, oil and other organic substances, residues from soap, detergents, cleaning agents, etc. and generally low concentrations of pathogens (Ridderstolpe 2004). Grey water in general has low content of any metals or organic pollutants, but depending on the building it can increase with the addition of environmentally harmful substances (Ridderstolpe 2004). The content of metals or organic compounds greatly depends on usage of substances like paints, solvents, etc. (Ridderstolpe 2004).

Often times, grey water is confused with black water (toilet waste). Black water is a term used to describe water containing fecal matter or urine or both (Wikipedia 2007a). Black water is highly polluted and difficult to treat because of the high concentrations of mostly organic pollution (Lindstrom 1992). Grey water or reclaimed water can be used for a wide variety of uses (Anderson 2007). In the southwestern U.S where home irrigation supplies are limited, rainfall is low, and evapotranspiration is high, grey water reuse is an effective alternative to save potable water (Popkin 1979). Grey water can be used in the application of:

- Irrigation of golf courses
- Irrigation of food crops
- Irrigation of parks, playgrounds and school yards
- Irrigation of business parks
- Irrigation of freeway landscaping
- Commercial car washes
- Dust control
- Housing associations
- Industrial cooling towers
- Industrial process water
- Irrigation of pasture for animals
- Decorative fountains
- Commercial laundries

Previous studies also show that reclaimed water is as good as potable supplies for food crops (Bastian 2006).

Water conservation is therefore a well-timed area of research and grey water reuse has been considered to reduce the costs as well as the extent of treatment (Surendran and Wheatley 1997). On an average, sixty percent of the domestic household waste water load is grey water (Popkin 1979). Reusing grey water can provide 190 to 380 liters (50 to 100 gallons) per day for outdoor use and toilet flushing for a typical household (Rocky Mountain Institute 2007). It is difficult to predict the quantity of grey water produced in commercial constructions due to the wide variety of building types coupled with different occupancy rates.

Grey water systems

A dual water supply system which permits the reuse of grey water from lavatories, bath tubs, showers and other fixtures after proper treatment is called a grey water reuse system (Equaris 2007b). A wide array of grey water reuse systems is available, from simple low-cost systems to highly complex and costly systems, using crude to sophisticated technology (Gelt 2006). As shown in Figure 1, grey water reuse systems generally consist of a three-way diverter valve, a treatment assembly such as a sand filter, a holding tank, a bilge pump, and an irrigation or leaching system (PATH 2006; 2007).

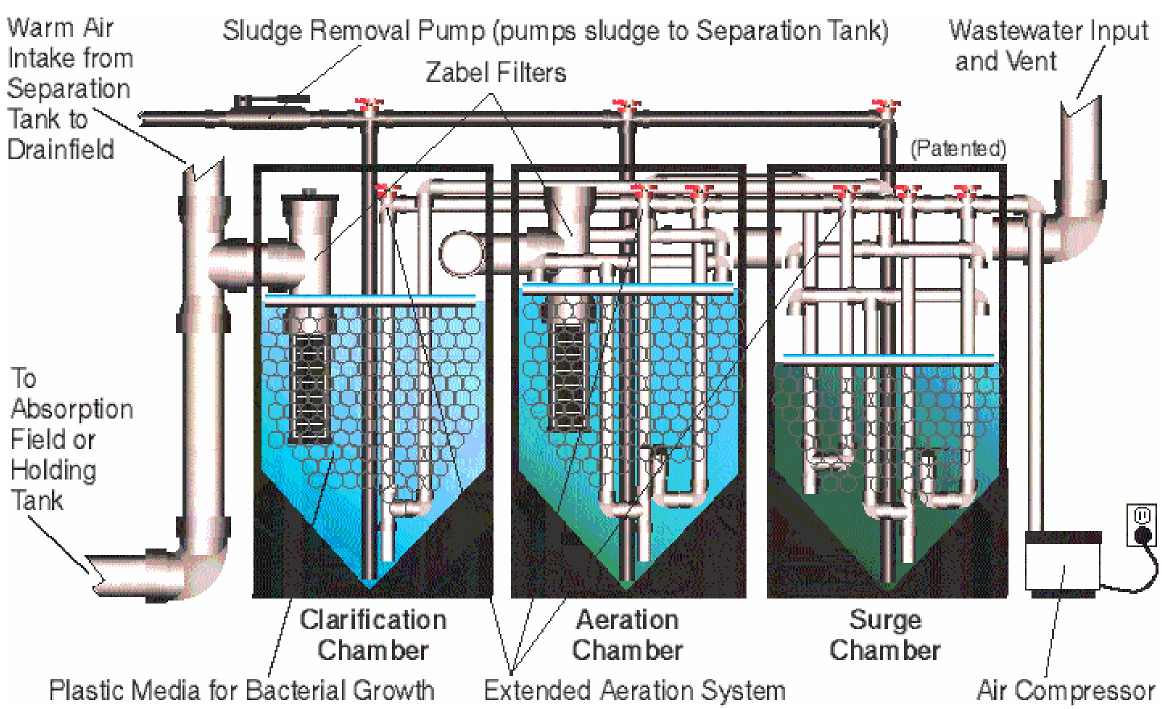

Fig. 1.Grey water treatment system
(Source: Equaris 2007b)

For commercial buildings, grey water is plumbed to a series of separate wastewater treatment and filtration tanks. The system consists of a surge tank for flow control, an aeration tank to produce aerobic conditions and a clarification tank to return the settled solids back to the surge tank. An air compressor is required to provide an abundant amount of air to continuously circulate the wastewater. The standard wastewater treatment technology of extended aeration is used and water is cleaned by bacteria which are grown on the interior surface walls of the tanks. Approximately 151 liters (forty gallons) of wastewater per person per day is estimated after separating grey water from toilet water (Equaris 2007a). The treated waste water generated after the aeration and circulation process is disinfected before reuse (Equaris 2007a).

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. Figure 2 shows a list of countries where water is reclaimed and its percentage of total water used. 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. Figure 3 shows a summary of water treatment guidelines and mandatory standards in the United States and other countries. Following are summaries of grey water programs in these countries:

Kalmar, Sweden - In Kalmar, Sweden the grey water purification plant is designed to boost the subsurface flow of water and biological interactions of plants and microorganisms in a triplicate riparian ecotone. The water from the building in Kalmar which is solely grey water is treated in the wetpark and reused in the building after purification. “Wetpark” is a name chosen for this constructed wet land (Gunther 1995). The construction cost for the above mentioned grey water purification system is about $700 per person which also includes the cost of buffer tanks and pumps. The calculations show that the residual nutrient content of the water would be about 0.06 mg nitrogen per liter and 0.02 mg phosphorus per liter, which is less than 1/10 of drinking water standards. After one year of use in Sweden, tests have given the results of 0.007 mg nitrogen per liter which is highly efficient (Gunther 1999).

Country	Total Annual Water Withdrawal			Annual Reclaimed Water Usage			Reclaimed Water as Percent of Total
	Year	Mm^3	MG	Year	Mm^3	MG	
Algeria	1990	4,500	1,188,900	-	-	-	-
Bahrain	1991	239	63,144	1991	15	3,963	6%
Cyprus	1993	211	55,746	1997	23	6,077	11%
Egypt	1993	55,100	14,557,420	2000	700	184,940	1%
Iran	2001	81,000	21,400,200	1999	154	40,687	0.20%
Iraq	1990	42,800	11,307,760	-	-	-	-
Israel	1995	2,000	528,400	1995	200	52,840	10%
Jordan	1993	984	259,973	1997	58	15,324	6%
Kuwait	1994	538	142,140	1997	80	21,136	15%
Kyrgyzstan	1990	11,036	2,915,711	1994	0.14	37	0%
Lebanon	1994	1,293	341,611	1997	2	528	0.20%
Libya	1994	4,600	1,215,320	1999	40	10,568	1%
Morocco	1991	11,045	2,918,089	1994	38	10,040	0.30%
Oman	1991	1,223	323,117	1995	26	6,869	2%
Qatar	1994	285	75,297	1994	25	6,605	9%
Saudi Arabia	1992	17,018	4,496,156	2000	217	57,331	1%
Syria	1993	14,410	3,807,122	2000	370	97,754	3%
Tajikistan	1989	12,600	3,328,920	-	-	-	-
Tunisia	1990	3,075	812,415	1998	28	7,398	1%
Turkey	1992	31,600	8,348,720	2000	50	13,210	0%
Turkmenistan	1989	22,800	6,023,760	-	-	-	-
U. A. Emirates	1995	2,108	556,934	1999	185	48,877	9%
Yemen	1990	2,932	774,634	2000	6	1,585	0%

Fig. 2. Source of water in different countries
(Source : EPA 2004)

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 10^{12} liters of water in 1996. The treated waste water is used for toilet flushing, train washing, dilution water for night (human feces), landscape irrigation and snow melting (Maeda et al. 1996).

Country/Region	Fecal Coliforms (CFU/100ml)	Total coliforms (cfu/100 ml)	Helminth eggs (#/L)	BOD_5 (ppm)	Turbidity (NTU)	TSS (ppm)	DO (%of Sat)	pH	Chlorine residual (ppm)
Australia (New South Wales)	<1	<2/50	--	>20	<2	--	--	--	--
Arizona	<1	--	--	--	1	--	--	4.5-9	--
California	--	2.2	--	--	2	--	--	--	--
Cyprus	50	--	--	10	--	10	--	--	--
EC bathing water	100 (g) 2,000 (m)	500 (g) 10,000 (m)	--	--	2 (g) 1 (m)	--	80-120	6-9	--
France	<1000	--	<1	--	--	--	--	--	--
Florida (m)	25 for any sample for 75%	--	--	20	--	5	--	--	1
Germany (g)	100(g)	500 (g)	--	20 (g)	1-2 (m)	30	80-120	6-9	--
Japan (m)	10	10	--	10	5	--	--	6-9	--
Israel	--	2.2 (50%) 12(80%)	--	15	--	15	0.5	--	0.5
Italy	--	--	--	--	--	--	--	--	--
Kuwait Crops not eaten raw	--	10,000	--	10	--	10	--	--	1
Kuwait Crops eaten raw		100		10		10			1
Oman 11A	<200	--	--	15	--	15	--	6-9	--
Oman 11B	<1000			20		30		6-9	
South Africa	0 (g)	--	--	--	--	--	--	--	--
Spain (Canary islands)	--	2.2	--	10	2	3	--	6.5-8.4	1
Texas (m)	75(m)	--	--	5	3	--	--	--	--
Tunisia	--	--	<1	30		30	7	6.5-8.5	--
UAE	--	<100	--	<10	--	<10	--	--	--
United Kingdom Bathing Water Criteria	100 (g) 2000 (m)	500 (g) 10000 (m)	--	--	2 (g) 1 (m)	--	80-120	6-9	--
US EPA (g)	14 for any sample, 0 for 90 %	--	--	10	2	--	--	6-9	1
WHO (lawn irrigation)	200 (g) 1000 (m)	--	--	--	--	--	--	--	--

Note: (g) signifies that the standard is a guideline and (m) signifies that the standard is a mandatory regulation
Source: Adapted from Cranfield University, 2001. Urban Water Recycling Information Pack, UK

Fig. 3. Summary of water treatment guidelines and mandatory standards in the United States and other countries
(Source: EPA 2004)

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).

Berlin, Germany - Even though Germany does not face severe water problems, the water conservation measures practiced in Berlin and other parts of Germany are commendable (Nolde 2005). Grey water reuse has been practiced with greater interest and variable success (Nolde 2005).

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, programs may still be permitted on a case-by-case basis (EPA 2004).

Regulations and guidelines vary considerably from state to state. States such as Arizona, California, Colorado, Florida, Georgia, Hawaii, Massachusetts, Nevada, New Jersey, New Mexico, North Carolina, Ohio, Oregon, Texas, Utah, Washington, and Wyoming have developed regulations or guidelines that strongly encourage water reuse as a water resources conservation strategy (EPA 2004). Out of these states, Arizona, California, Colorado, Florida, Hawaii, Massachusetts, Nevada, New Jersey, North Carolina, Oregon, South Dakota, Texas, Utah, and Washington were the states that specific regulations and guidelines regarding the use of recycled water for purposes other than irrigation (EPA 2004).

Following are the states where reclaimed water is used for the following unrestricted urban reuse categories (EPA 2004):

- Toilet Flushing: Arizona, California, Florida, Hawaii, Massachusetts, New Jersey, North Carolina, Texas, Utah, and Washington
- Fire Protection: Arizona, California, Florida, Hawaii, New Jersey, North Carolina, Texas, Utah, and Washington
- Construction Purposes: Arizona, California, Florida, Hawaii, New Jersey, North Carolina, Oregon, Utah, and Washington
- Landscape or Aesthetic Impoundments: Arizona, California, Colorado, Florida, Hawaii, Nevada, New Jersey, North Carolina, Oregon, Texas, and Washington
- Cleaning Streets: Arizona, California, Florida, Hawaii, North Carolina, and Washington.

Figure 4 summarizes state reuse regulations and guidelines in the United States, and Figure 5 shows the states with regulations for each type of application.

State	Regulations	Guidelines	No Regulations or Guidelines [1]	Change from 1992 Guidelines for Water Reuse [2]	Unrestricted Urban Reuse	Restricted Urban Reuse	Agricultural Reuse Food Crops	Agricultural Reuse Non-Food Crops	Unrestricted Recreational Reuse	Restricted Recreational Reuse	Environmental Reuse	Industrial Reuse	Groundwater Recharge	Indirect Potable Reuse
Alabama		●		N		●		●						
Alaska	●			NR				●						
Arizona	●			U	●	●	●	●		●				
Arkansas		●		N	●	●	●	●						
California [3]	●			U	●	●	●	●	●	●		●	●	●
Colorado	● [4]			GR	●	●	●	●	●	●				
Connecticut			●	N										
Delaware	●			GR	●	●		●						
Florida	●			U	●	●	●	●			●	●	●	●
Georgia		●		U	●	●		●						
Hawaii		●		U	●	●	●	●		●		●	●	●
Idaho	●			N	●	●	●	●						
Illinois	●			U	●	●		●						
Indiana	●			U	●	●	●	●						
Iowa	●			NR		●		●						
Kansas		●		N	●	●	●	●						
Kentucky			●	N										
Louisiana			●	N										
Maine			●	N										
Maryland		●		N		●		●						
Massachusetts		●		NG	●	●		●					●	●
Michigan	●			N			●	●						
Minnesota			●	N										
Mississippi			●	N										
Missouri	●			N		●		●						
Montana	●			GR	●	●	●	●						
Nebraska	●			GR		●		●						
Nevada	●			GR	●	●	●	●	●	●				
New Hampshire			●	N										
New Jersey		●		RG	●	●	●	●				●		
New Mexico		●		N	●	●	●	●						
New York		●		N				●						
North Carolina	●			U	●	●						●		
North Dakota		●		U	●	●		●						
Ohio		●		NG	●	●		●						
Oklahoma	●			GR		●	●	●						
Oregon	●			N	●	●	●	●	●	●		●		
Pennsylvania		●		NG				●						
Rhode Island			●	N										
South Carolina	●			GR	●	●		●						
South Dakota		●		N	●	●		●			●			
Tennessee	●			N	●	●		●						
Texas	●			U	●	●	●	●	●	●		●		
Utah	●			U	●	●	●	●	●	●		●		
Vermont	●			N				●						
Virginia			●	N										
Washington		●		U	●	●	●	●	●	●	●	●	●	●
West Virginia	●			N			●	●						
Wisconsin	●			N				●						
Wyoming	●			U	●	●	●	●						

(1) Specific regulations on reuse not adopted: however, reclamation may be approved on a case-by-case basis

(2) N - no change; NR - no guidelines or regulations to regulations; U - updated guidelines or regulations; NG - no guidelines or regulations to guidelines; GR - guidelines to regulations; RG - regulations to guidelines

(3) Has regulations for landscape irrigation excluding residential irrigation; guidelines cover all other uses

Fig. 4. Summary of state reuse regulations and guidelines
(Source: EPA 2004)

Type of Reuse	Number of States
Unrestricted Urban	28
Irrigation	28
Toilet Flushing	10
Fire Protection	9
Construction	9
Landscape Impoundment	11
Street Cleaning	6
Restricted Urban	34
Agricultural (Food Crops)	21
Agricultural (Non-food Crops)	40
Unrestricted Recreational	7
Restricted Recreational	9
Environmental (Wetlands)	3
Industrial	9
Groundwater Recharge (Nonpotable Aquifer)	5
Indirect Potable Reuse	5

Fig. 5. Number of states with regulations or guidelines for each type of reuse application
(Source: EPA 2004)

California and Florida have brought together comprehensive inventories of reuse projects by type of reuse application. These inventories are prepared by the California Water Resources Control Board (CWRCB) in Sacramento and the Florida Department of Environmental Protection (FDEP) in Tallahassee (EPA 2004). Figure 6 and Figure 7 shows water reuse in Florida and California respectively. There are 438 reuse systems in Florida's water reuse inventory (Florida DEP 2007).

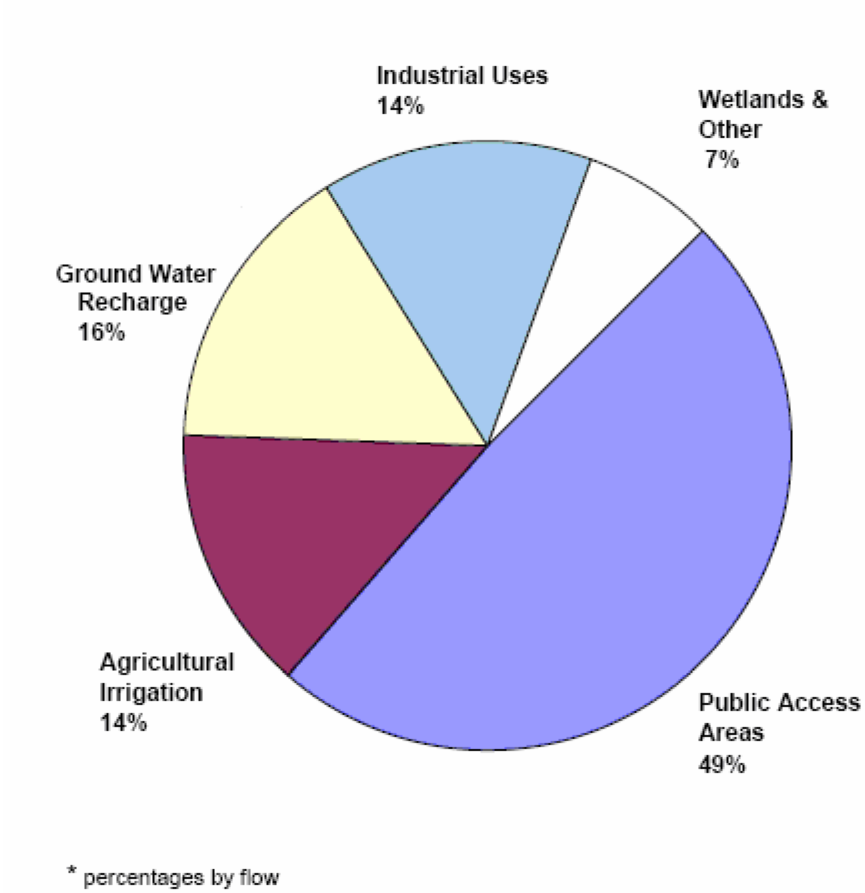

Fig. 6. Water reuse in Florida
(Source: Florida DEP 2006b)

Before 1992, grey water reuse was not legal in many states in the U.S., including California. With the drought of 1976-77, California considered using grey water reuse in houses and it was a new concept (Ingham 1980). The California Legislature passed a law in 1992 legalizing grey water use in the cities and counties of California and the California Department of Water Resources (CDWR) has adopted standards for the installation of grey water systems and the use of grey water (Gelt 2006). To meet the needs of California's projected population of 52 million in the year 2030, the state's water supply board is emphasizing on water conservation, recycling, desalination, trading and storage of surface and groundwater. Since the 1890s, Californians have been reusing municipal wastewater for agriculture, farm irrigation, landscape irrigation, etc.

Currently, California is recycling approximately 500,000 acre-feet of water per year for various uses (EPA 2003).

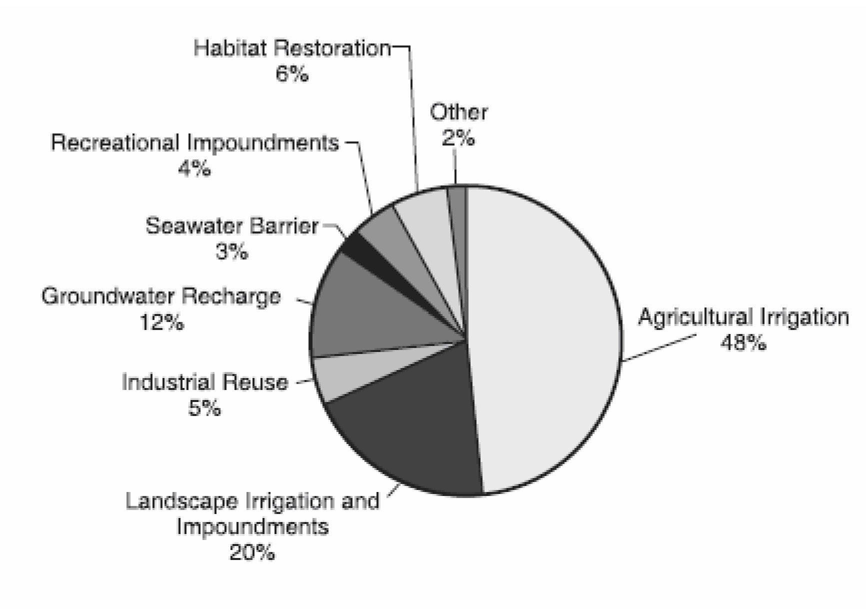

Fig. 7. California reuse by type
(Source: EPA 2003)

Based on the inventories, current regulations and guidelines may be divided into the following reuse categories:

- Unrestricted urban reuse – irrigation of public areas like parks, playgrounds, school yards, and residences; toilet flushing, air conditioning, fire protection, construction, ornamental fountains, and aesthetic impoundments (EPA 2004).
- Restricted urban reuse – irrigation of areas in which public access can be restricted, such as golf courses, cemeteries, and highway medians (EPA 2004).
- Agricultural reuse on food and non-food crops – irrigation of food crops and non-food crops such as fodder, fiber, sod farms, etc. (EPA 2004).

- Recreational reuse – Restricted and unrestricted use of water for recreational reuse like fishing, boating and non-contact activities (EPA 2004).
- Environmental reuse - To create manmade wetlands, enhance natural wetlands, etc. (EPA 2004).
- Industrial reuse – For cooling towers, boiler-feed water, process water, and general wash down (EPA 2004).

In urban areas of Texas, residential and commercial landscape irrigation accounts for more than 25 percent of total water consumption (USGBC 2003). By using efficient technologies to conserve water including using grey water for landscape irrigation, toilet and urinal flushing, custodial purposes and building systems, load on potable water can be greatly reduced. The population of Texas is expected to double between year 2000 (20,851,790) and the year 2060 (45,558,282) but the state's water planning areas will not grow equally (TWDB 2006).

The Texas Water Development Board is emphasizing equally on water conservation measures like Florida and California. Reclaimed water is currently being used in Eleven regional water planning groups (Regions, A, C, D, E, F, H, I, K, L, M, and O) (TWDB 2007). In its latest report, Texas Water Development Board (TWDB) has projected approximately 360,000 acre-feet of water reuse per year in 2010 and is projected to increase to about 370,000 acre-feet per year by 2060 from direct and indirect reuse (TWDB 2006).

Construction project planning

Any construction project, big or small, is a process with several phases and numerous participants working together to accomplish a common goal. Every construction project can be divided into mainly three phases (Hendrickson 2003):

1. Project planning
2. Project execution
3. Project operation

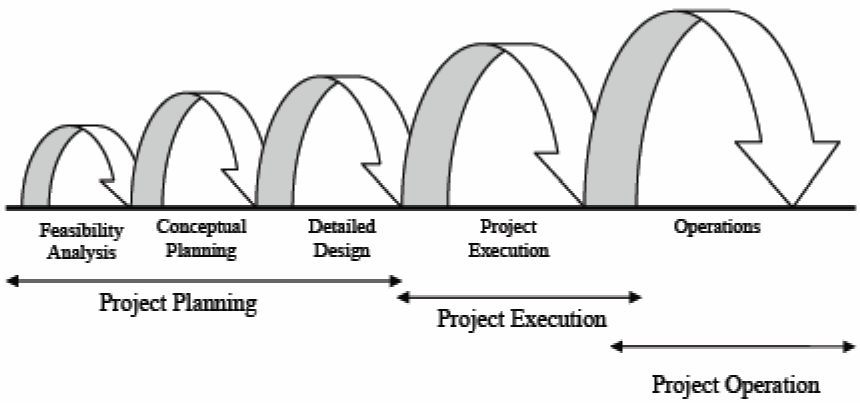

Fig. 8. Construction project planning
(Source: Hendrickson 2003)

A well-planned project is unlikely to face unforeseen events which may otherwise hamper the project's progress. As shown in Figure 8, the first phase, the planning phase, is imperative for any green building project as it involves identifying opportunities in terms of attaining various points by site selection, problems, debating on different options, and conducting feasibility analyses on market-available technologies.

In this study, the researcher studied different factors which affect the project team's decision when it comes to implementing a grey water reuse system. The necessity for recycled water reuse and treatment strategies greatly depends on the location of the project. For example, the demand of water in southern California exceeds the available water supply, and as a result the state of California Water Plan and Metropolitan Water District Integrated Water Resources Plan recommends the use of recycled water to alleviate water shortages (Inland Empire Utilities Agency 2007).

Project cost and schedule are two important entities which get impacted by adding new equipment and components to a construction project. Even though a project may attain one or multiple points by implementing a particular technology to conserve energy, water or material, capital cost and the fear of schedule delays are important from a project's standpoint. For example, if a project plans to implement a grey water reuse system, dual sanitary and grey water distribution piping doubles construction piping costs, and disinfection treatment, filtration, overflow protection add to the cost of construction, operation and maintenance (USGBC 2005).

A feasibility analysis is conducted on each possible solution and it is based on a careful study on various factors including capital cost, project schedule, payback time, maintenance cost, LEED credits, tax incentives, complexity of a system, etc. Complexity includes the intricacies faced during the installation, execution and maintenance of any system or equipment. After considering positive and negative effects of all the above mentioned factors, a consensus is reached between the project team members including the stakeholders after a meticulous examination of available budget, economic and environmental considerations.

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 (Appendix A) 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.

The data collected was analyzed using the Statistical Package for the Social Sciences (SPSS) program. A non-parametric test called the Binomial Test was used to analyze the data to answer the first research question. Cross tabulation and Chi-square Tests were used to analyze the data to answer the second research question. The results data after coding for answering the first research question:

Research question 1

What is the effect of the implementation of grey water reuse systems on construction project schedule and cost of green building projects in the U.S. In order to answer this question, the proportion of the research population was studied.

Research question 1a

Null hypothesis: Fifty percent of the research population perceives that the implementation of a grey water reuse system has no effect on the capital cost of the project. $\Pi = .5$, where Π is the proportion of the population.

Alternate hypothesis: More than 50 percent of the research population perceives that the implementation of a grey water reuse system affects the capital cost of the project. $\Pi \neq .5$, where Π is the proportion of the population.

Table 1. Binomial test results for question 1a

		Category	N	Observed Prop.	Test Prop.	Asymp. Sig. (2-tailed)
Was grey water reuse system implemented or being considered?	No	.00	34	.52	.50	.902
	Yes	1.00	32	.48		
	TOTAL		66	1.00		
Did grey water reuse system affect the capital cost of the project?	Yes	1.00	50	.76	.50	.000
	No	.00	16	.24		
	TOTAL		66	1.00		

The SPSS test results for research question 1a are shown in Table 1. Since the significance value of capital cost is .000, which is less than .05, at a confidence interval (CI) of 95 percent, we reject the null hypothesis and it can be inferred that capital costs of more or less than 50 percent of projects are affected by the implementation of grey water reuse systems in green building projects in the U.S. Since the observed proportion (.76) is greater than the test proportion of .5, it can also be also inferred that there are more projects which claim that the capital cost of the project is affected by the implementation of the grey water reuse system.

Sub question 1b

Null hypothesis: Fifty percent of the research population perceives that the implementation of a grey water reuse system affects the project schedule of the project. Π = .5, where Π is the proportion of the population.

Alternate hypothesis: More than 50 percent of the research population perceives that the implementation of a grey water reuse system does not affect the project schedule of the project. Π ≠ .5, Π is the proportion of the population.

Table 2. Binomial test results for question 1b

		Category	N	Observed Prop.	Test Prop.	Asymp. Sig. (2-tailed)
Was grey water reuse system implemented or being considered?	Yes	.00	34	.52	.50	.902
	No	1.00	32	.48		
	TOTAL		66	1.00		
Did grey water reuse system affect the capital cost of the project schedule?	No	.00	60	.91	.50	.000
	Yes	1.00	6	.09		
	TOTAL		66	1.00		

The SPSS test results for research question 1b are shown in Table 2. Since the significance value of the project is .00, which is less that .01, at a CI of 99 percent, we reject the null hypothesis and it can be inferred that project schedules of more or less than 50 percent of projects are affected or not affected by the implementation of grey water reuse systems in green building projects in the U.S. Since the observed proportion (.91) is greater than the test proportion of .5, it can also be inferred that there are more projects which claim that there is no effect on project schedule by the implementation of a grey water reuse system.

Research question 2

What is the influence of capital cost, maintenance cost, project schedule, LEED credits, water conservation issues, tax incentives, pay back time and complexity of the system on the implementation of grey water reuse systems in the U.S.

In this case, grey water reuse is the response variable. The effect of following factors is being studied by the research:

1. Capital costs
2. Maintenance costs
3. Project schedule
4. Water conservation issues
5. Tax incentives
6. LEED credits
7. Pay back time
8. Complexity of the grey water reuse system

Table 3. Case processing summary of all the factors

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Grey water reuse system * Capital Cost	66	100.0%	0	.0%	66	100.0%
Grey water reuse system * Maintenance Cost	66	100.0%	0	.0%	66	100.0%
Grey water reuse system * LEED Credits	66	100.0%	0	.0%	66	100.0%
Grey water reuse system * Water Conservation Issues	66	100.0%	0	.0%	66	100.0%
Grey water reuse system * Tax Incentives	66	100.0%	0	.0%	66	100.0%
Grey water reuse system * Payback time	66	100.0%	0	.0%	66	100.0%
Grey water reuse system * Complexity of the System	66	100.0%	0	.0%	66	100.0%

Research question 2a

Null Hypothesis: Implementation of a grey water reuse system in a green building project is independent of capital cost of the system.

Alternate hypothesis: Implementation of a grey water reuse system in a green building project is dependent on capital cost of the system.

Table 4. Cross table for grey water vs. capital cost

			Was "capital cost" a factor which affected your decision		
			No	Yes	TOTAL
Was grey water reuse system implemented or being considered?	No	Count	3	31	34
		% within grey water reuse system	8.8%	91.2%	100.0%
	Yes	Count	13	19	32
		% within grey water reuse system	40.6%	59.4%	100.0%
TOTAL		Count	16	50	66
		% within grey water reuse system	24.2%	75.8%	100.0%

Table 5. Chi-square test results for research question 2a

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	9.078(b)	1	.003		
Continuity Correction(a)	7.429	1	.006		
Likelihood Ratio	9.586	1	.002		
Fisher's Exact Test				.004	.003
Linear-by-Linear Association	8.940	1	.003		
N of Valid Cases	66				

The SPSS test results for research question 2a are shown in Tables 4, 5, and 6. Since the significance value is equal to .003 which is less than .05, at a CI of 95 percent, we reject the null hypothesis and accept the alternate hypothesis that implementation of a grey water reuse system in a green building project is dependent on capital cost or in other words, capital cost is a factor affecting project team's decision on the implementation of a grey water reuse system in a green building project.

Research question 2b

Null hypothesis: Implementation of a grey water reuse system in a green building project is independent of maintenance cost of the system.

Alternate hypothesis: Implementation of a grey water reuse system in a green building project is dependent on maintenance cost of the system.

Table 6. Cross table for grey water vs. maintenance cost

			Was "Maintenance cost" a factor which affected your decision		
			No	Yes	TOTAL
Was grey water reuse system implemented or being considered?	No	Count	15	19	34
		% within grey water reuse system	44.1%	55.9%	100.0%
	Yes	Count	19	13	32
		% within grey water reuse system	59.4%	40.6%	100.0%
TOTAL		Count	34	32	66
		% within grey water reuse system	51.5%	48.5%	100.0%

Table 7. Chi-square test results for research question 2b

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.536(b)	1	.215		
Continuity Correction(a)	.986	1	.321		
Likelihood Ratio	1.543	1	.214		
Fisher's Exact Test				.231	.160
Linear-by-Linear Association	1.513	1	.219		
N of Valid Cases	66				

The SPSS test results for research question 2b are shown in Tables 6 and 7. Since the p-value is .160, which is greater than .05, at 95 percent CI, we cannot reject the null hypothesis that implementation of a grey water reuse system in a green building project is independent of maintenance cost of the system.

Research question 2c

Null hypothesis: Implementation of a grey water reuse system in a green building project is independent of LEED credits.

Alternate hypothesis: Implementation of a grey water reuse system in a green building project is dependent on LEED credits.

Table 8. Cross table for grey water vs. LEED credits

			Was "LEED credits" a factor which affected your decision		
			No	Yes	TOTAL
Was grey water reuse system implemented or being considered?	No	Count	26	8	34
		% within grey water reuse system	76.5%	23.5%	100.0%
	Yes	Count	7	25	32
		% within grey water reuse system	21.9%	78.1%	100.0%
TOTAL		Count	33	33	66
		% within grey water reuse system	50.0%	50.0%	100.0%

Table 9. Chi-square test results for research question 2c

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	19.654(b)	1	.000		
Continuity Correction(a)	17.531	1	.000		
Likelihood Ratio	20.774	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	19.357	1	.000		
N of Valid Cases	66				

The SPSS test results for research question 2c are shown in Tables 8 and 9. Since the p-value is .00, which is less than .05, at 95 percent CI, we reject the null hypothesis and infer that implementation of grey water reuse system in a green building project is dependent on LEED credits.

Research question 2d

Null hypothesis: Implementation of a grey water reuse system in a green building project is independent of water conservation issues in the locality.

Alternate hypothesis: Implementation of a grey water reuse system in a green building project is dependent on water conservation issues in the locality.

Table 10. **Cross table for grey water vs. water conservation issues**

			Was "water conservation issues" a factor which affected your decision		
			No	Yes	TOTAL
Was grey water reuse system implemented or being considered?	No	Count	25	9	34
		% within grey water reuse system	73.5%	26.5%	100.0%
	Yes	Count	18	14	32
		% within grey water reuse system	56.3%	43.8%	100.0%
TOTAL		Count	43	23	66
		% within grey water reuse system	65.2%	34.8%	100.0%

Table 11. **Chi-square test results for research question 2d**

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.168(b)	1	.141		
Continuity Correction(a)	1.474	1	.225		
Likelihood Ratio	2.180	1	.140		
Fisher's Exact Test				.197	.112
Linear-by-Linear Association	2.135	1	.144		
N of Valid Cases	66				

The SPSS test results for research question 2d are shown in Tables 10 and 11. Since the p-value is .112, which is greater than .05, at 95 percent CI, we cannot reject the null hypothesis that implementation of a grey water reuse system in a green building project is independent of water conservation issues in the locality.

Research question 2e

Null hypothesis: Implementation of a grey water reuse system in a green building project is independent of tax incentives.

Alternate hypothesis: Implementation of a grey water reuse system in a green building project is dependent on tax incentives.

Table 12. Cross table for grey water vs. tax incentives

			Was "tax incentives" a factor which affected your decision		
			No	Yes	TOTAL
Was grey water reuse system implemented or being considered	No	Count	29	5	34
		% within grey water reuse system	85.3%	14.7%	100.0%
	Yes	Count	28	4	32
		% within grey water reuse system	87.5%	12.5%	100.0%
TOTAL		Count	57	9	66
		% within grey water reuse system	86.4%	13.6%	100.0%

Table 13. Chi-square test results for research question 2e

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.068(b)	1	.794		
Continuity Correction(a)	.000	1	1.000		
Likelihood Ratio	.068	1	.794		
Fisher's Exact Test				1.000	.540
Linear-by-Linear Association	.067	1	.796		
N of Valid Cases	66				

The SPSS test results for research question 2e are shown in Tables 12 and 13. Since the p-value is .540, which is greater than .05, at 95 percent CI, we cannot reject the null hypothesis that implementation of a grey water reuse system in a green building project is independent of tax incentives.

Research question 2f

Null hypothesis: Implementation of a grey water reuse system in a green building project is independent of payback time of the system.

Alternate hypothesis: Implementation of a grey water reuse system in a green building project is dependent on payback time of the system.

Table 14. Cross table for grey water vs. payback time

			Was "payback time" a factor which affected your decision		
			No	Yes	TOTAL
Was grey water reuse system implemented or being considered?	No	Count	21	13	34
		% within grey water reuse system	61.8%	38.2%	100.0%
	Yes	Count	20	12	32
		% within grey water reuse system	62.5%	37.5%	100.0%
TOTAL		Count	41	25	66
		% within grey water reuse system	62.1%	37.9%	100.0%

Table 15. Chi-square test results for research question 2f

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.004(b)	1	.951		
Continuity Correction(a)	.000	1	1.000		
Likelihood Ratio	.004	1	.951		
Fisher's Exact Test				1.000	.576
Linear-by-Linear Association	.004	1	.951		
N of Valid Cases	66				

The SPSS test results for research question 2f are shown in Tables 14 and 15. Since the p-value is .576, which is greater than .05, at 95 percent CI, we cannot reject the null hypothesis that implementation of a grey water reuse system in a green building project is independent of payback time of the system.

Research question 2g

Null hypothesis: Implementation of a grey water reuse system in a green building project is independent of complexity of the system.

Alternate hypothesis: Implementation of a grey water reuse system in a green building project is dependent on complexity of the system.

Table 16. Cross table for grey water vs. complexity of the system

			Was "complexity of the system" a factor which affected your decision		
			No	Yes	TOTAL
Was grey water reuse system implemented or being considered?	No	Count	12	22	34
		% within grey water reuse system	35.3%	64.7%	100.0%
	Yes	Count	21	11	32
		% within grey water reuse system	65.6%	34.4%	100.0%
TOTAL		Count	33	33	66
		% within grey water reuse system	50.0%	50.0%	100.0%

Table 17. Chi-square test results for research question 2g

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	6.066(b)	1	.014		
Continuity Correction(a)	4.914	1	.027		
Likelihood Ratio	6.163	1	.013		
Fisher's Exact Test				.026	.013
N of Valid Cases	66				

The SPSS test results for research question 2f are shown in Table 16 and 17 respectively.Since the p-value is .013, which is less than .05, at 95 percent CI, we reject the null hypothesis and infer that complexity of a grey water system is a factor which affects the project team's decision to implement a grey water reuse system in a green building project.

Case studies

Ten case studies of green building projects which had incorporated grey water reuse systems were selected from the USGBC website (USGBC 2007b), Office of energy efficiency and renewable energy under the Department of Energy (DOE) website (USDOE 2007b) and general web search on green building projects. Out of the ten, three platinum green building projects in southern California were visited to study various aspects related to grey water and are included in this study.

Case study A

This commercial office which was completed in 2003 is a platinum rated building under the USGBC LEED rating system. It is approximately 1400 sq. meter (15,000 sq. feet), located in Santa Monica, California and is a renovation of a 1917 building, last renovated in 1975. The total project cost excluding the land is $5,100,000. The Office is located in downtown Santa Monica, allowing the use of public transportation and existing roads and utility lines. The office is also equipped with showers and bicycle racks which encourage employees to bike or walk to work.

The building is plumbed to accommodate grey water. Grey water from showers and sinks is treated and reused for flushing toilets or for watering plants, thus using potable water only when necessary. Rainwater is collected, pre-filtered, and integrated into the grey water reuse system. Dual-flush toilets, waterless urinals, a high-efficiency dishwasher, porous paving which allows storm water to percolate into the ground, etc. are other strategies incorporated in the facility to conserve water. As a result, the building uses no potable water for outdoor uses. The implementation of a grey water reuse system affected the project cost but did not affect the schedule. The LEED credits, water conservation issues, etc. were some of the factors which affected the project team's decision to implement a grey water reuse system.

Case study B

This platinum rated project, which was completed in 2003, is a water treatment plant or utility agency which supplies fresh water to 7 cities. It is located in Chino, California. According to the project's manager, the facility expects to save more than $800,000 each year in energy costs alone. Improved water and energy efficiencies resulted in significant operating cost savings (USGBC 2007b). The building site anchors the new 22-acre Chino Creek Park, which will restore the natural drainage and ecological function of the site while providing public recreation and habitat for endangered and sensitive species.

Reclamation features of this headquarters complex building include drive isles, parking lots, and walking paths made of permeable materials designed to capture storm water or allow it to infiltrate. Recycled water is used for an onsite, drip-irrigation system and water features. Dual-flush toilets and ultra-low-flow urinals utilize 100 percent recycled water from treatment facilities and use 27 percent less water than conventional toilets and urinals (USGBC 2007b). Wastewater treated at the processing plant is also used to irrigate all landscaped areas and will eventually supply water to neighboring farms and industry where potable water is neither required nor desired. Native and drought-tolerant landscaping requires less water than conventional landscaping. Several water-conservation strategies employed in this project helped reduce potable water demand by approximately 73 percent and the building does not use potable water for outdoor uses. The waste water treatment agency highly prioritizes water reuse. Hence, neither the capital costs, maintenance costs, complexity of the system, nor any other factor which usually discourages projects from implementing grey water reuse systems, affected their decision.

Case study C

This 466 sq. meter (5,020 sq. feet) interpretive center which is proximate to downtown Los Angeles, California cost $5,500,000 and was built in 2003. The platinum rated project, which occupies 17 acres of the park leased from the City, is focused on environmental education. The center is operated entirely off-grid, using only power generated onsite and uses only 25,000 kWh of energy each year, which is around 5 kWh per square foot. The Center treats all wastewater onsite and uses only 30 percent of the water typically consumed by a conventional building of the same size. Storm water collected by the development is kept onsite and diverted to a water quality treatment basin before being released to help recharge groundwater.

The initial plan was to recycle grey water and black water for toilet flushing but the City of Los Angeles did not approve it. However, the building is equipped with dual plumbing lines to facilitate grey water reuse in the future if approved by the city of Los Angeles. Indoor and outdoor potable water use is 2,67,628 liters (70,700 gallons) per year and 68,100 liters (18,000 gallons) per year, respectively (USDOE 2007a). The LEED credits, water conservation issues, the spirit of sustainability, etc. were factors which encouraged the project team to install dual piping.

Summary of results

Water conservation measures practiced in a LEED project

Frequency tables and bar graphs obtained from the research survey point us to interesting results in addition to the ones attained from the statistical analysis. From Figure 9, it can be noticed that out of the 66 projects which participated in the research survey, more than 90 percent employ water efficient landscaping for conserving potable water, followed by the installation of water efficient fixtures, urinals, etc. (eighty three percent) (Fig.9.). Grey water reuse systems were considered by 38 percent of the project teams.

Effect of the implementation of a grey water reuse system on capital cost and schedule

According to 76 percent of the projects which implemented grey water reuse systems, capital cost of the project is affected by the implementation of a grey water reuse system. 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.

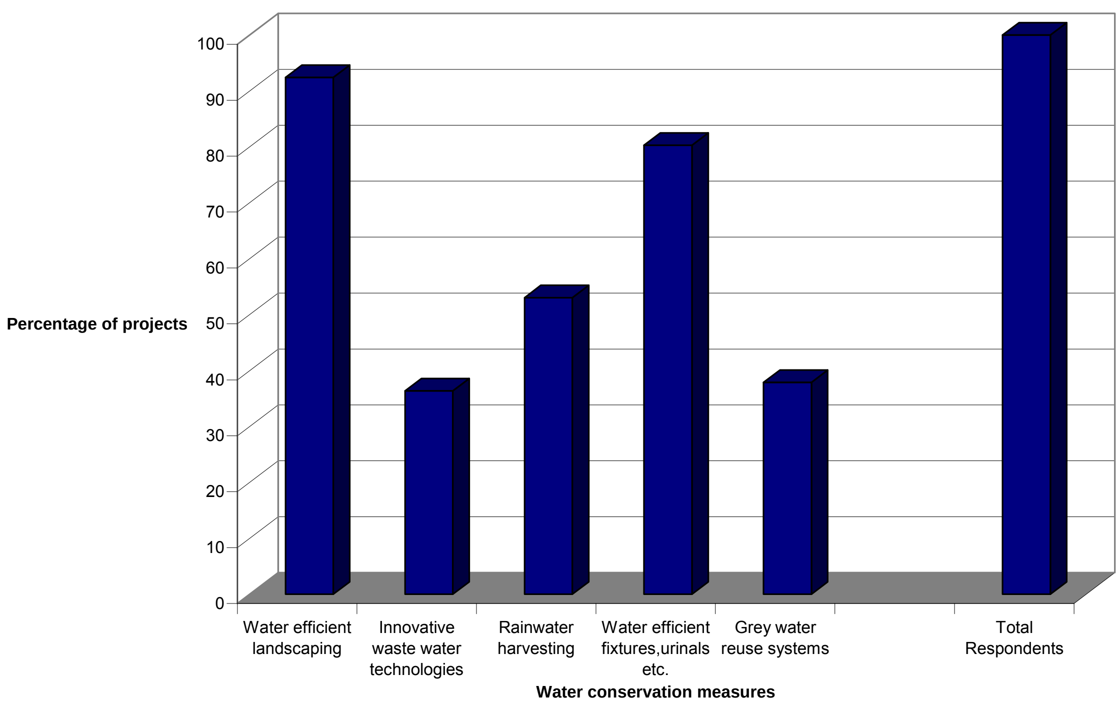

Fig. 9. Frequency of water conservation measures in a LEED project

Factors influencing the implementation of a grey water reuse system

There are a multitude of factors a design team or project team should consider 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, complexity of the system, project schedule, maintenance cost, water conservation issues in the locality, tax incentives, and payback time of the system. It can be inferred from Figure 10 that out of all the factors, 76 percent of projects consider capital cost as a major factor affecting the project team's decision to implement a grey water reuse system in a green building project. Fifty percent of the projects feel that complexity of the system and LEED credits are important factors which influence their decision.

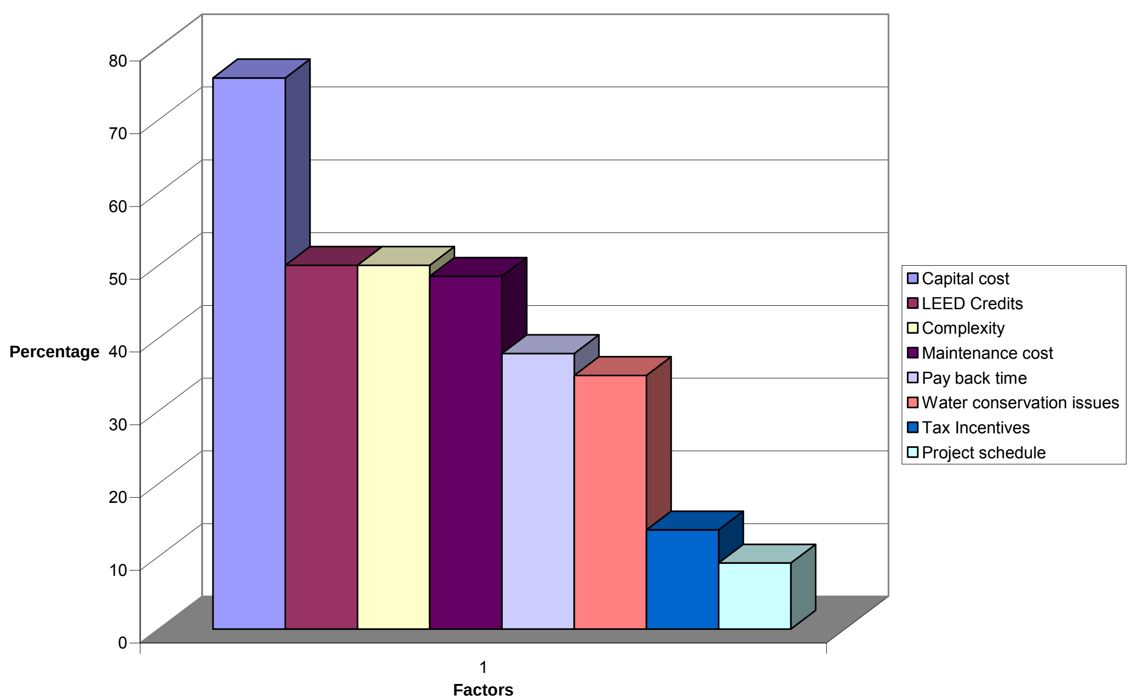

Fig. 10. Factors affecting the implementation of grey water reuse system

It is interesting to learn that out of 66 projects which participated in the survey, the projects which were considering grey water reuse systems or the ones which implemented it felt that LEED credits are an important aspect, while the projects which were not planning to implement or have not implemented a grey water reuse system reported that LEED credits were not an important factor.

Maintenance cost is an important aspect and many projects (48 percent) claimed that it was important; however, the percentage was not significant (less than the test proportion of 50 percent) to reject the alternate hypothesis. Thirty-eight percent of projects felt that payback time was an important factor and 35 projects claimed that water conservation issues in the locality were a factor but the percentages were not significant enough to reject the null hypothesis. Project schedule (9 percent) and tax incentives (14 percent) were least opted by the participating projects.

Individual questions seeking project opinions on capital cost, LEED credits, maintenance cost, water conservation issues, etc. were asked and bar graphs tell the results. Figures 11, 12, 13, and 14 show the opinions of project teams regarding the influence of capital cost, LEED credits, water conservation issues and tax incentives respectively on the implementation of a grey water reuse system.

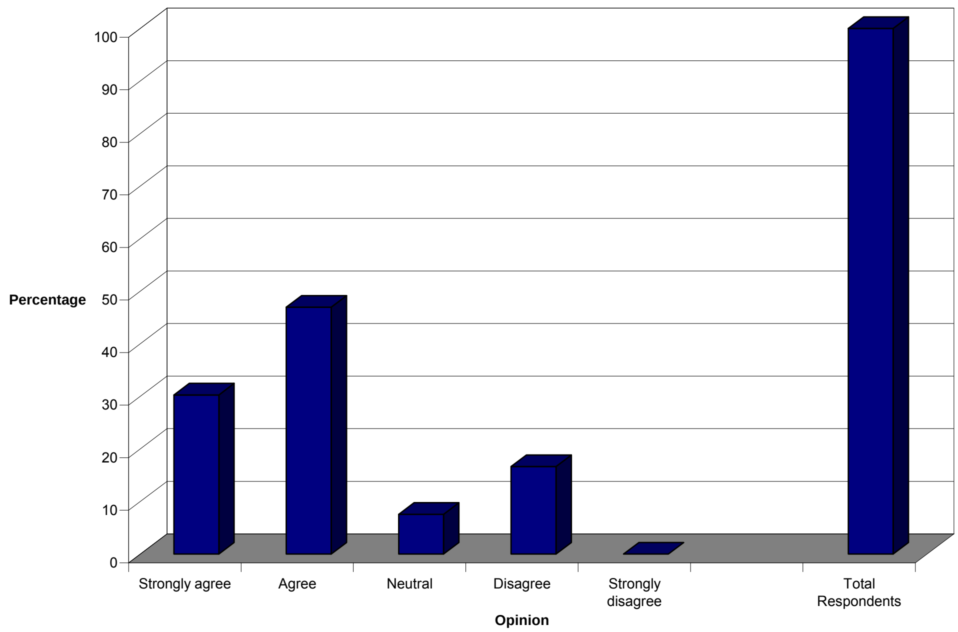

Fig. 11. Influence of capital cost on the implementation of grey water reuse system

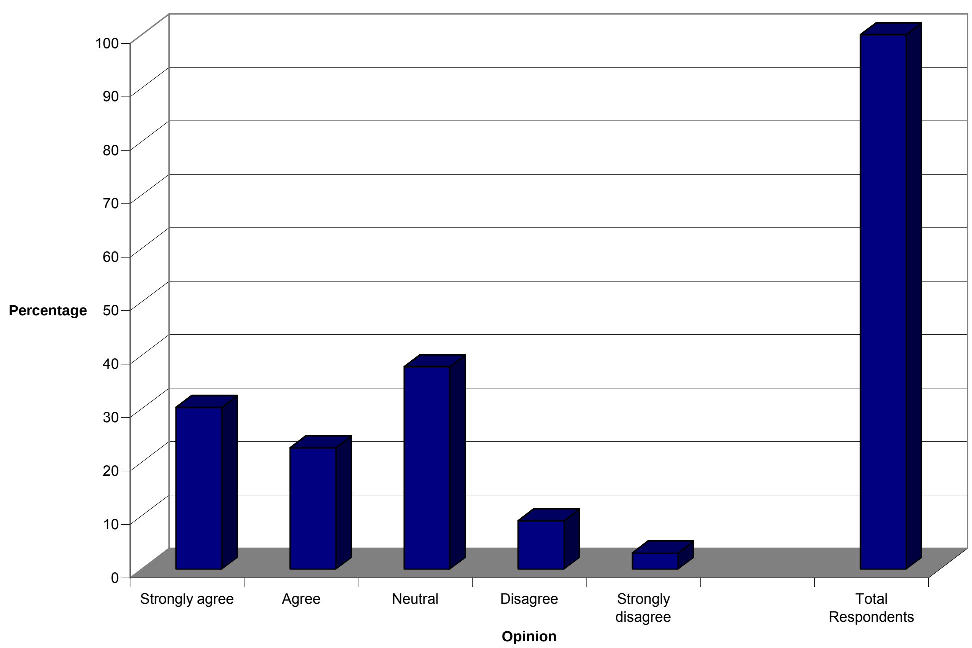

Fig. 12. Influence of LEED credits on the implementation of grey water reuse system

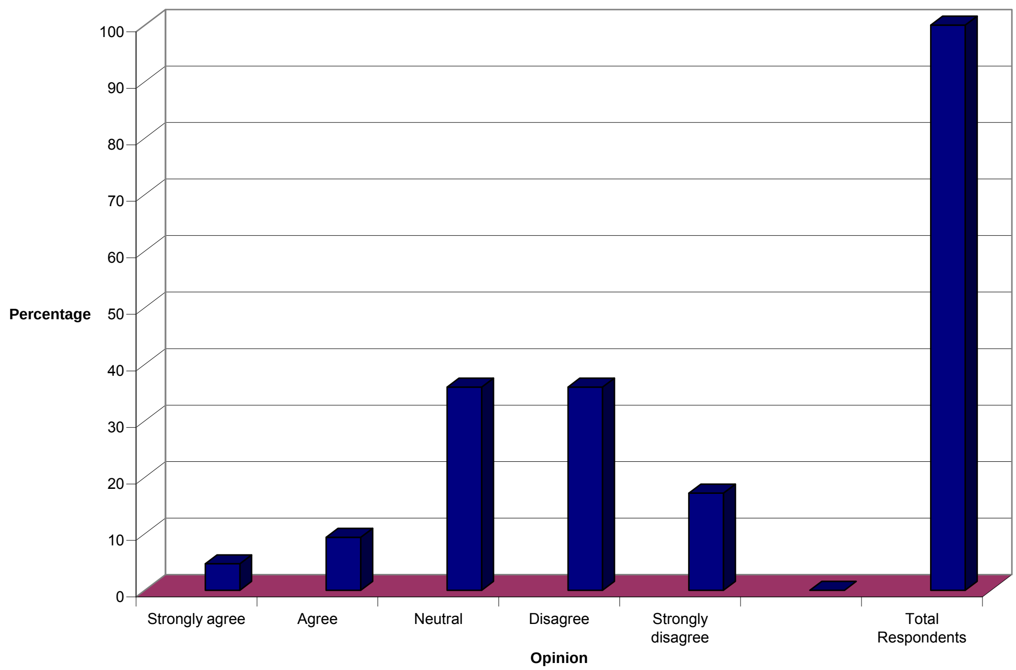

Fig. 13. Influence of tax incentives on the implementation of grey water reuse system

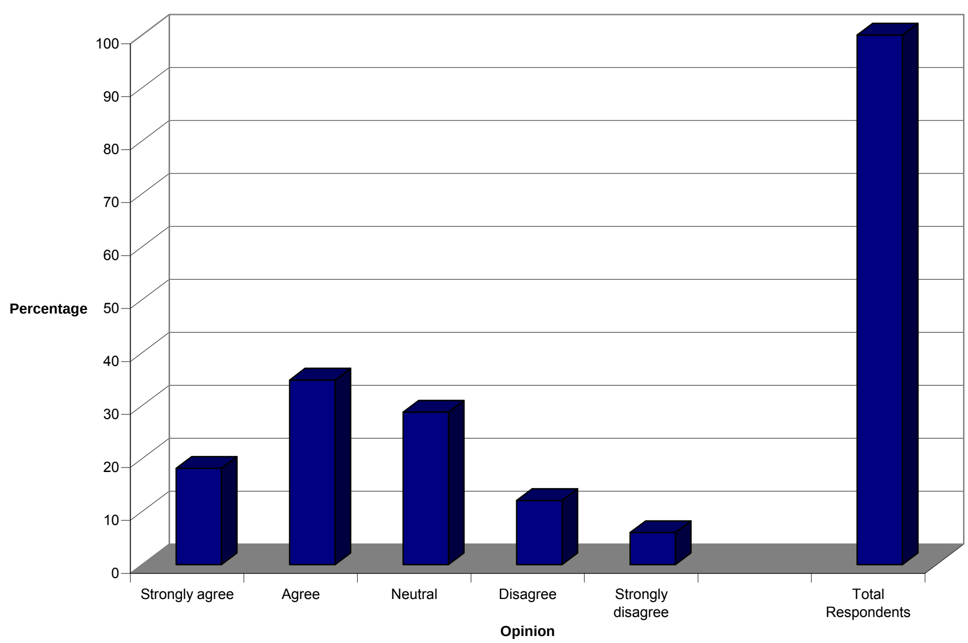

Fig. 14. Influence of complexity of the system on the implementation of grey water reuse system

CONCLUSIONS AND RECOMMENDATIONS

Conclusions of the research

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.

Additional factors

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

As discussed in the previous section, 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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APPENDIX A

RESEARCH SURVEY FOR CERTIFIED PROJECTS UNDER LEED

Exit this survey >>

M.S. - Construction Management - Research Survey for Certified Projects under LEED

1. Effects of the implementation of grey water reuse systems on construction project schedule and cost

Thank you for participating in this study, (Effects of the implementation of grey water reuse systems on construction project schedule and cost). The purpose of this study is to conduct a feasibility analysis on the use of grey water reuse systems and their sustainability in commercial constructions in the United States. The study includes registered and certified projects with the Leadership in Energy and Environmental Design (LEED) green building rating system under U.S. Green Building Council. You were selected to be a possible participant because you are part of a green building project certified or registered under the LEED rating system. The study will include 250 participants who are over eighteen years of age. The survey will take 7-10 minutes to complete.

Please note the following characteristics of this study:
- Your participation is voluntary and your identity will remain confidential.
- Confidentiality will be insured by sharing the data collected only with the Committee chair and members of my graduate advisory committee.
- The data collected on the survey will be used for the research and the results may be published in a journal related to building construction.

If you have any questions, please feel free to contact:

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This research study has been reviewed by the Institutional Review Board (IRB) – Human Subjects in Research, Texas A&M University. For research related problems or questions regarding subjects' rights, you can contact the IRB through Ms. Melissa McIlhaney, IRB Program Coordinator, Office of Research Compliance, 979-458-4067, mcilhaney@tamu.edu.

Questionnaire for data collection -Certified Projects under LEED.

*** 1. General information of the Project:**
Project Name:

*** 2. Location:**

*** 3. LEED Rating:**

*** 4. Did the project team include measures or strategies to attain points under "Water Efficiency" credits (LEEDNC 2.1 /2.2)?**

YES	NO
☐	☐

*** 5. How many points did the project team attain under "Water efficiency" credits (LEED NC 2.1/2.2)?**

1	2	3	4	5
☐	☐	☐	☐	☐

*** 6. Please check the box(es) for the following water efficient practices that were included in the project.**

Water efficient landscaping	Innovative waste water technologies	Rainwater harvesting	Water efficient fixtures, urinals etc.	Grey water reuse systems
☐	☐	☐	☐	☐

*** 7. Was grey water reuse systems considered as a strategy for water conservation?**

YES	NO
☐	☐

8. If yes, did the implementation of grey water reuse system affect the project schedule

YES	NO
☐	☐

9. If yes, did the implementation of grey water reuse system affect the overall project budget?

YES	NO
☐	☐

*** 10. Please check the factors which influenced the project team's decision on implementing/ not implementing the installation ofgrey water reuse system.**

Capital cost	Maintenance cost	Project schedule	LEED Credits	Water conservation issues in the locality	Tax Incentives	Payback time
☐	☐	☐	☐	☐	☐	☐

*** 11. Please check the appropriate boxes on how these factors affected your decision to implement/ not implement a greywater reuse system. a. Capital costs influenced the design team's decision to implement/not implement a grey water reuse system.**

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
☐	☐	☐	☐	☐

*** 12. b. Maintenance cost influenced the design team's decision to implement/not implement a grey water reuse system.**

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
☐	☐	☐	☐	☐

13. c.LEED Credits influenced the design team's decision to implement/not implement a grey water reuse system

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
☐	☐	☐	☐	☐

*** 14. d. Water conservation issues in the locality influenced the design team's decision to implement/not implement a grey water reuse system.**

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
☐	☐	☐	☐	☐

*** 15. e.Tax incentives by federal/local government influenced the design team's decision to implement/not implement a grey water reuse system.**

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
☐	☐	☐	☐	☐

*** 16. f. Payback time influenced the design team's decision to implement/not implement a grey water reuse system.**

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
☐	☐	☐	☐	☐

*** 17. g. Complexity of the Grey water reuse system and LEED documentation influenced the design team'sdecision to implement/not implement a grey water reuse system.**

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
☐	☐	☐	☐	☐

18. Were there any additional factors which affected the decision to implement/not implement grey water reuse systems?

19. Thank You very much for completing the survey.
Your response truely matters a lot for this research survey. You can fill in multiple surveys if you have been part of or are part of multiple LEED projects.

The data collected will be analysed using statistical tools and the results will be used for my Thesis -"Effects of the implementation of grey water reuse systems on contsruction project schedule and cost"

Thank you once again for your cooperation.

Contact me if you have any questions or suggestions - jeslin@tamu.edu

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Done >>

APPENDIX B

RESEARCH SURVEY FOR REGISTERED PROJECTS UNDER LEED

Exit this survey >>

Research Survey for Registered projects under LEED.

1. Effects of the implementation of grey water reuse systems on construction project schedule and cost

Thank you for participating in this study, (Effects of the implementation of grey water reuse systems on construction project schedule and cost). The purpose of this study is to conduct a feasibility analysis on the use of grey water reuse systems and their sustainability in commercial constructions in the United States. The study includes registered and certified projects with the Leadership in Energy and Environmental Design (LEED) green building rating system under U.S. Green Building Council. You were selected to be a possible participant because you are part of a green building project certified or registered under the LEED rating system. The study will include 250 participants who are over eighteen years of age. The survey will take 7-10 minutes to complete.

Please note the following characteristics of this study:
• Your participation is voluntary and your identity will remain confidential.
• Confidentiality will be insured by sharing the data collected only with the Committee chair and members of my graduate advisory committee.
• The data collected on the survey will be used for the research and the results may be published in a journal related to building construction.

If you have any questions, please feel free to contact:

Jeslin K Varghese
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Dr.Charles Graham (Committee chair)
Interim Department Head
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This research study has been reviewed by the Institutional Review Board (IRB) – Human Subjects in Research, Texas A&M University. For research related problems or questions regarding subjects' rights, you can contact the IRB through Ms. Melissa McIlhaney, IRB Program Coordinator, Office of Research Compliance, 979-458-4067, mcilhaney@tamu.edu.

Questionnaire for data collection - Registered Projects under LEED

1. General information of the Project:
Project Name:

* **2. Location:**

* **3. Expected LEED Rating:**

* **4. Does the project team plan to include measures or strategies to attain points under "Water Efficiency"credits (LEED NC 2.1 /2.2)?**

YES	NO
☐	☐

* **5. How many points does the project team expect to attain under "Water efficiency" credits (LEED NC 2.1/2.2)?**

0	1	2	3	4	5
☐	☐	☐	☐	☐	☐

* **6. Which one of the following practices are included in the project to attain points under "Water Efficiency"?**

Water efficient landscaping	Innovative waste water technologies	Rainwater harvesting	Water efficient fixtures, urinals etc.	Grey water reuse systems	None of the above
☐	☐	☐	☐	☐	☐

* **7. Are grey water reuse systems considered as a strategy for water conservation?**

YES	NO
☐	☐

* **8. Please check the factors which influenced or may influence the project team's decision on implementinga grey water reuse system. (Please check more than one if you think they influenced the project team's decision.)**

Capital cost	Maintenance cost	Project schedule	LEED Credits	Water conservation issues in the locality	Tax Incentives	Payback time
☐	☐	☐	☐	☐	☐	☐

* **9. Please check the appropriate number on how these factors affected or may effect your decision to implement a grey water reuse system.**

a. Capital cost influenced the design team's decision to implement a grey water reuse system.

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
☐	☐	☐	☐	☐

* **10. b. Maintenance cost influenced the design team's decision to implement a grey water reuse system.**

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
☐	☐	☐	☐	☐

11. c.LEED Credits influenced the design team's decision to implement a grey water reuse system

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
☐	☐	☐	☐	☐

* **12. d. Water conservation issues in the locality influenced the design team's decision toimplement a grey water reuse system.**

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
☐	☐	☐	☐	☐

* **13. e.Tax incentives by federal/local government influenced the design team's decision toimplement a grey water reuse system.**

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
☐	☐	☐	☐	☐

* **14. f. Payback time influenced the design team's decision to implement a grey water reuse system.**

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
☐	☐	☐	☐	☐

* **15. g. Complexity of the Grey water reuse system and LEED documentation influenced the design team'sdecision to implement a grey water reuse system.**

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
☐	☐	☐	☐	☐

16. Were there any additional factors which affected the decision to implement grey water reuse systems?

17. Thank You very much for completing the survey.
Your response truely matters a lot for this research survey. You can fill in multiple surveys if you have been part of or are part of multiple LEED projects.

The data collected will be analysed using statistical tools and the results will be used for my Thesis -"Effects of the implementation of grey water reuse systems on contsruction project schedule and cost"

Thank you once again for your cooperation.

Contact me if you have any questions or suggestions: jeslin@tamu.edu
Jeslin K. Varghese, LEED® AP
MS candidate-Construction Management
Texas A&M University
College Station,TX-77840

Done >>

APPENDIX C

IRB APPROVAL

TEXAS A&M UNIVERSITY
VICE PRESIDENT FOR RESEARCH - OFFICE OF RESEARCH COMPLIANCE

1186 TAMU
College Station, TX 77843-1186
1500 Research Parkway, Suite B-150

979.458.1467
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http://researchcompliance.tamu.edu

Institutional Biosafety Committee   Institutional Animal Care and Use Committee   Institutional Review Board

DATE: 24-Jan-2007

MEMORANDUM

TO: VARGHESE, JESLIN KADUVINAL
TAMU-CONSTRUCTION SCIENCE(00022)

FROM: Office of Research Compliance
Institutional Review Board

SUBJECT: Initial Review

Protocol Number: 2007-0027

Title: Grey Water Reuse Systems - Feasibility Analysis

Review Category: Exempt from IRB Review

The Institutional Review Board (IRB) has determined that the referenced protocol application meets the criteria for exemption and no further review is required. However, any amendment or modification to the protocol must be reported to the IRB and reviewed before being implemented to ensure the protocol still meets the criteria for exemption.

This determination was based on the following Code of Federal Regulations:
(http://www.hhs.gov/ohrp/humansubjects/guidance/45cfr46.htm)
45 CFR 46.101(b)(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior, unless: (a) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (b) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

APPENDIX D

LEED V 2.1 CHECKLIST

LEED Version 2.1 Registered Project Checklist

LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN

Project Name
City, State

Yes	?	No				
			Sustainable Sites			14 Points
Y			Prereq 1	**Erosion & Sedimentation Control**		Required
			Credit 1	**Site Selection**		1
			Credit 2	**Urban Redevelopment**		1
			Credit 3	**Brownfield Redevelopment**		1
			Credit 4.1	**Alternative Transportation**, Public Transportation Access		1
			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms		1
			Credit 4.3	**Alternative Transportation**, Alternative Fuel Vehicles		1
			Credit 4.4	**Alternative Transportation**, Parking Capacity and Carpooling		1
			Credit 5.1	**Reduced Site Disturbance**, Protect or Restore Open Space		1
			Credit 5.2	**Reduced Site Disturbance**, Development Footprint		1
			Credit 6.1	**Stormwater Management**, Rate and Quantity		1
			Credit 6.2	**Stormwater Management**, Treatment		1
			Credit 7.1	**Landscape & Exterior Design to Reduce Heat Islands**, Non-Roof		1
			Credit 7.2	**Landscape & Exterior Design to Reduce Heat Islands**, Roof		1
			Credit 8	**Light Pollution Reduction**		1

Yes	?	No				
			Water Efficiency			5 Points
			Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%		1
			Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation		1
			Credit 2	**Innovative Wastewater Technologies**		1
			Credit 3.1	**Water Use Reduction**, 20% Reduction		1
			Credit 3.2	**Water Use Reduction**, 30% Reduction		1

Yes	?	No				
			Energy & Atmosphere			17 Points
Y			Prereq 1	**Fundamental Building Systems Commissioning**		Required
Y			Prereq 2	**Minimum Energy Performance**		Required
Y			Prereq 3	**CFC Reduction in HVAC&R Equipment**		Required
			Credit 1	**Optimize Energy Performance**		1 to 10
			Credit 2.1	**Renewable Energy**, 5%		1
			Credit 2.2	**Renewable Energy**, 10%		1
			Credit 2.3	**Renewable Energy**, 20%		1
			Credit 3	**Additional Commissioning**		1
			Credit 4	**Ozone Depletion**		1
			Credit 5	**Measurement & Verification**		1
			Credit 6	**Green Power**		1

Yes	?	No				
			Materials & Resources			13 Points
Y			Prereq 1	**Storage & Collection of Recyclables**		Required

Yes	?	No	Credit	Description	Points
			Credit 1.1	**Building Reuse**, Maintain 75% of Existing Shell	1
			Credit 1.2	**Building Reuse**, Maintain 100% of Shell	1
			Credit 1.3	**Building Reuse**, Maintain 100% Shell & 50% Non-Shell	1
			Credit 2.1	**Construction Waste Management**, Divert 50%	1
			Credit 2.2	**Construction Waste Management**, Divert 75%	1
			Credit 3.1	**Resource Reuse**, Specify 5%	1
			Credit 3.2	**Resource Reuse**, Specify 10%	1
			Credit 4.1	**Recycled Content**, Specify 5% (post-consumer + ½ post-industrial)	1
			Credit 4.2	**Recycled Content**, Specify 10% (post-consumer + ½ post-industrial)	1
			Credit 5.1	**Local/Regional Materials**, 20% Manufactured Locally	1
			Credit 5.2	**Local/Regional Materials**, of 20% Above, 50% Harvested Locally	1
			Credit 6	**Rapidly Renewable Materials**	1
			Credit 7	**Certified Wood**	1

Yes	?	No	Indoor Environmental Quality		15 Points
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
			Credit 1	**Carbon Dioxide** (CO_2) **Monitoring**	1
			Credit 2	**Ventilation Effectiveness**	1
			Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
			Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
			Credit 4.2	**Low-Emitting Materials**, Paints	1
			Credit 4.3	**Low-Emitting Materials**, Carpet	1
			Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber	1
			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
			Credit 6.1	**Controllability of Systems**, Perimeter	1
			Credit 6.2	**Controllability of Systems**, Non-Perimeter	1
			Credit 7.1	**Thermal Comfort**, Comply with ASHRAE 55-1992	1
			Credit 7.2	**Thermal Comfort**, Permanent Monitoring System	1
			Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
			Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

Yes	?	No	Innovation & Design Process		5 Points
			Credit 1.1	**Innovation in Design**: Provide Specific Title	1
			Credit 1.2	**Innovation in Design**: Provide Specific Title	1
			Credit 1.3	**Innovation in Design**: Provide Specific Title	1
			Credit 1.4	**Innovation in Design**: Provide Specific Title	1
			Credit 2	**LEED™ Accredited Professional**	1

Yes	?	No	Project Totals (pre-certification estimates)		69 Points

Certified 26-32 points **Silver** 33-38 points **Gold** 39-51 points **Platinum** 52-69 points

VITA

Jeslin Kaduvinal Varghese, LEED AP

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www.people.tamu.edu/~jeslin — College Station, TX 77843

Education

Master of Science in Construction Management — August 2007
Texas A&M University, College Station, TX
Bachelor of Technology in Civil Engineering — May 2003
University of Kerala, College of Engineering Trivandrum, India

Related Professional Experience

Assistant Project Engineer — May 2006 – Aug 2006
Weston Solutions Inc., Offutt Air Force Base, Omaha, NE

Research Assistant — Jan 2006 – May 2006
Technology Commercialization Center, Texas A&M University

Planning and Construction Engineer — Jan 2004 – June 2005
Flash Engineers and Builders, Bangalore, India

Site Engineer — June 2003 – Dec 2003
Flash Engineers and Builders, Bangalore, India

Skills

MS Project, Primavera, RS Means-Cost Works, AutoCAD, e Quest, Web designing and all major office applications

Awards

Edward and Hutchinson Scholarship — January 2006

Activities

Founder & President, USGBC Emerging Green Builders, TAMU
Graduate Advisor, Global Justice, TAMU
Charity challenge 2004, British Aerospace Systems, Bangalore
Help Age India and International Red Cross Society