December 2008

Green Building Water Infrastructure Technologies Analysis at EPA NCER

Adam James Brooks
Worcester Polytechnic Institute

Brian Wilbur Robie
Worcester Polytechnic Institute

Fidelis Wambui
Worcester Polytechnic Institute

Manh-Hung Vo Le
Worcester Polytechnic Institute

Project Number: CXP0802

IQP Division: 44

Analysis of Green Building Water Infrastructure Technologies at the EPA NCER

An Interactive Qualifying Project Report
Submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
In partial fulfillment of the requirement for the
Degree of Bachelor of Science

By
Adam Brooks
Manh-Hung V. Le
Brian Robie
Fidelis Wambui

Submitted on:

December 19, 2008

Approved:
Professor Creighton Peet, Lead Advisor
Professor Kaveh Pahlavan, Co-Advisor

Abstract

The National Center for Environmental Research (NCER) funds extramural research for the Environmental Protection Agency. Our goal was to provide future research recommendations concerning green building and more specifically water infrastructure. Categorizing NCER's past projects and research, interviewing with principal investigators, and meeting with employees of various EPA offices have allowed us to identify existing research gaps. NCER's future solicitations should consider water reuse, green roofs, and improving cooling towers. NCER should also focus on ways to improve social acceptance of green building, thus advancing implementation of green technologies, devices, and practices.

Acknowledgements

We would like to thank the following individuals and organizations for their support and effort that contributed to our project's success. We would foremost like to thank the National Center of Environmental Research (NCER) for sponsoring our project. We would like to thank our liaisons, Dr. Diana Bauer and Mrs. April Richards for their continuous guidance and support. Without their help, our project would not have been a success. We would like to thank Dr. William Sanders, Mr. James Gantry, Mrs. Cynthia Nolt-Helms, and Mrs. Angela D. Page for helping us with NCER's program information. We would like to thank Ms. Abby Hall, Mr. Jamal Kadri, Ms. Alison Kinn, Mr. Ken Sandler, Dr. Audrey Levine, and Ms. Stephanie Tanner for taking their time to share their knowledge with us.

We would like to thank all of the project investigators from the various institutions that conducted interviews with us.

We would like to dearly thank Professor Creighton Peet and Professor Kaveh Pahlavan for their continuous support and guidance. Their input was invaluable towards our project's success.

Thank you again for all of your support.

Adam Brooks
Manh-Hung Le
Brian Robie
Fidelis Wambui

Authorship Page

While there is a primary author for every section, each group member contributed to the editing and revision of each section.

Commonly Used Acronyms and Abbreviations

CNS – Collaborative science and technology Network for Sustainability

CSO – Combined Sewer Overflow

CWA – Clean Water Act

DOE – Department of Energy

EPA – Environmental Protection Agency

LEED – Leadership in Energy and Environmental Design

NCER – National Center for Environmental Research

NSF – National Science Foundation

P3 – People, Prosperity, Planet

PI – Principal Investigator

SBIR – Small Business Innovation Research

SDWA – Safe Drinking Water Act

STAR – Science To Achieve Results

TSE – Technology for Sustainable Environment

USGBC – United States Green Building Council

Table of Contents

Table of Figures

Table of Tables

Executive Summary

Building construction and operation threaten the environment in ways varying from releasing carbon dioxide to polluting water sources. In the United States, buildings consume 12% of the total available fresh water, 30% of the materials, and 70% of the electricity produced (US EPA, 2004). Aging water and wastewater infrastructure systems are overloaded from the increasing population and incessant construction throughout the United States (Grigg, 2003). Green building practices such as green roofs and water reuse can reduce these impacts and improve efficiency significantly. In the United States, the Environmental Protection Agency (EPA) has begun studying green technology as a potential solution for reducing the negative impacts of buildings. The EPA has a very broad scope of environmental research ranging from water and air pollution to larger infrastructural impacts. Within green technologies consideration is given to energy, materials, construction, and more related to our study, water and wastewater infrastructure. From 2003 to 2007, less than 2% of the EPA's total research funding went to green building research, with most of it being extramurally distributed through grants (USGBC, 2008a). Of the 2% devoted to green building research, only 11% was used for water and storm water research. Considering the current environmental issues and the benefits of green buildings, this level of research on green water technologies is insufficient.

The goal of this project was to provide recommendations to the EPA's National Center for Environmental Research (NCER) regarding potential future research areas with a focus on the impacts of green building on water and wastewater infrastructure. To achieve our goal we developed a series of 4 objectives to fulfill:

- Identify past and current green building research areas sponsored by NCER.
- Identify past and current green building research sponsored by other EPA offices and other organizations.

- Analyze technology and information gaps in green building research with a focus on water infrastructure
- Determine NCER's budgetary and regulatory constraints to recommend suitable future research priorities.

In order to determine the current direction of NCER's research, we identified 95 green building related projects from the 5547 projects in NCER's archive and categorized them. Our categories were based on the following three dimensions: *Scale, Media,* and *Approach.* An analysis of the *Scale* dimension, which refers to the size of a project, showed that the residential area has been significantly overlooked while emphasis has instead been placed on regional scale projects. The *Media* dimension encompasses categories that refer to the different green building research areas such as wastewater and stormwater. From *Media* we have identified that water reuse and green roofs have not received sufficient funding. An analysis of the *Approach* dimension, which describes the means of a project, illustrated a need for more social and metrics research. The 95 projects were funded in three main NCER programs: CNS, P3 and SBIR. Among these projects, CNS had the most funding while P3 had the largest number of projects. Our analysis of these programs showed a projected decrease in funding for future green building research. Overall, the level of green building research at NCER is deficient, especially in areas of water and wastewater infrastructure and more specifically water reuse and green roof technologies.

To further analyze NCER's research, we interviewed 11 principle investigators of 10 projects from our list of 95 green building related projects. These 10 projects covered a range of green building topics, from stormwater management to social acceptance. From these interviews, we determined that there is a need to better understand the impacts of green building to the larger infrastructures. Also, water reuse is facing challenges from regulators and the general public. Another key issue is the adaptation of green roof technologies to the different climatic regions within the U.S. Together these expert opinions gave more support to our identified gaps of water reuse, green roofs, and social acceptance needs.

We also interviewed sources from other EPA offices and other organizations, including the U.S. Green Building Council (USGBC). One conclusion we subscribe to is that there are many simple stormwater practices that can be implemented, but once again the need for social acceptance and education limit the technology from being adopted. Another issue identified is that the current LEED rating system does not address post occupancy performance and water efficiency. The EPA needs to cooperate with USGBC to jointly improve the LEED rating system to better address green building performance. The exponential increase in the number of LEED buildings emphasizes this need.

In order to make suitable final recommendations to NCER on future research priorities, we considered their total budget and the regulations that affect them such as the Safe Drinking Water Act. Unfortunately, the NCER budget has been decreasing over the past decade from approximately $110 million in 1999 to approximately $65 million in 2008. Programs like CNS, which was discontinued in 2007, have been negatively affected by this budget decrease resulting in an insufficient budget for future green building research. In order to effectively research the key areas of green building and water infrastructure NCER should allocate a sufficient budget and create a new program to replace the void CNS once filled.

After garnering and analyzing our data from NCER's archive, interviews with project investigators, and employees of EPA and USGBC, we developed two sets of recommendations for NCER. The first set of recommendations focuses on researching the gaps we have identified through the completion of our objectives. Water reuse, stormwater management practices and water infrastructure were identified as future focus areas for NCER. These areas include water reuse, both regional and onsite, water infrastructure, storm water management and the residential market.

The second set of recommendations concern future focus areas for specific programs within NCER. The P3 program is best suited for localized data collection, such as gathering green roof climatic data. The SBIR program should focus on water reuse technology, which would ultimately result in affordable products for consumers. Finally, the discontinued CNS program needs to be replaced with another sustainable oriented program to continue implementing sustainable design on a large scale. These recommendations will influence NCER's future solicitations to better address areas in need for green building research. They may also prove helpful in the formation of a green building research strategy across the EPA.

Ultimately green building is an integration of many environmental technologies. While we did consider all facets of green building research, our focus was on water infrastructure. We put our primary concentration on technologies dealing with the management of stormwater and wastewater and their resulting impacts on water infrastructure systems. Improving green building technology and implementation would minimize buildings impacts on both the environment and external infrastructures. With the limited budget available to NCER, our project sought to provide research priorities to better focus on aspects of green building that have been previously overlooked. Through our project, we hope these gaps will be better addressed through future NCER solicitations.

1 Introduction

Pollution is increasing worldwide. Water supplies face a daily onslaught of hazardous wastes. The atmosphere is a dumping ground for greenhouse gasses. Around the world the demand for more energy is on the rise, while the primary source for energy, fossil fuels, is quickly being consumed. Buildings are responsible for a large portion of energy and raw material consumption. In the United States, buildings consume 12% of the potable water, 30% of the materials, 70% of the electricity produced as well as account for 20% of the greenhouse gasses released and 45% of the waste sent to landfills (US EPA, 2004).

However, recent events and discoveries have brought about a change. People are becoming more aware of the costs of energy, both its monetary value and its environmental implications. Government agencies are pushing newly developed green technologies, including recycling, reuse, and efficiency to address these growing concerns. Green building, a recent trend to address the negative effects of buildings, consists of the use of environmentally friendly materials, pollution prevention through recycling, and an increase in energy efficiency.

The Environmental Protection Agency (EPA) has great influence on environmental regulations and policies in the US. To address current issues effectively the EPA needs to focus on areas of research that may have the biggest environmental impact. Over the past decade, one of the federal government's foci has been to continually improve the growing field of green building technologies. Since 1995 the number of green projects sponsored by EPA's National Center for Environmental Research (NCER) has risen to 95, with a total funding of over $7 million. However, this number is relatively small compared with other areas of NCER research. The EPA currently has no designated budget or research solicitations in place for green building research. Therefore, past green building related research was based exclusively upon individual interests and agendas. Outside the EPA, other government agencies, including the Department of Energy and the National

Science Foundation, and organizations such as the U.S. Green Building Council have sponsored research on technologies that are related to green building. Even with these advances in technologies, green building market penetration and social acceptance remain low.

Although it has been generally known that green building is more environmentally friendly than traditional building, there are still some unknown aspects. For example, there is little to no information available regarding any potential negative impacts of green building such as fire hazard or its overall impacts on different infrastructures such as water infrastructure. As a result the EPA is planning to conduct more research regarding green building technologies but it has not yet identified its foci. Being that the EPA does not have a green building research strategy, previous research performed within the EPA has been scattered among different offices. These research projects, especially those dealing with stormwater management and water recycling, often are not wholly integrated with green building. Ultimately, these gaps in information are potential challenges to the future development of green building technologies.

The purpose of our project is to provide the EPA with recommendations for future research areas regarding green building technologies, specifically those relating to water and wastewater infrastructure. Our first objective was to identify all the current and past research NCER has done on green building technology. Next we identified past research on green building by other offices within the EPA and by other organizations. We then analyzed the garnered research and identified the gaps in research with a focus on water infrastructure but also considered other green building aspects including energy and materials. We also considered the EPA's budgetary and regulatory constraints to carry out research in order to provide appropriate recommendations. The results of fulfilling these objectives were a categorized list and analyzed statistics on NCER and other's green building research and recommendations for future foci in green building technologies and water infrastructure.

2 Background

The purpose of this chapter is to provide background information on green building technologies and issues, specifically those concerning water and wastewater management. This chapter will also examine other aspects of green buildings relating to the environment including energy consumption, material selection, and construction. Finally, this chapter will look at the social acceptance and adoption of green building and green building technologies.

Building has been constructed long ago to provide a place for people to live in. We are spending an average of 20 hours per day inside buildings (Royal Institute of British Architects, 2008). Buildings dramatically affect our emotions, our health, our productivity, and all our everyday activities. If we are going to change the world, we have to start from the foundation of our living and working activities. We have to change the way buildings affect us, so that future generations can live in a healthier and better environment.

In the United States, buildings use 12% of the total available fresh water, 30% of the materials, 70% of the electricity produced as well as create 20% of the greenhouse gasses released and 45% of the waste sent to landfills (EPA, 2004). Building industries contributed over $1 trillion per year, 13.4% of the U.S. GDP, and provided jobs for 1.7 million people in America (USGBC, 2007).

Recognizing the importance and impacts of buildings on human health and the environment, countries around the world started to take action on changing the current building into a new construction concept, which uses resources more efficiently and has less negative environmental impacts, called green building. In 1990, The United Kingdom established Building Research Establishment's Environmental Assessment Method (BREEAM, 2008) in order to bring sustainable design concepts into the domestic housing market. In 2003, Green Building Council

Australia (2008) launched "Green Star" to provide certificate for green building. In the United States, the LEED started in 2000 to provide guidance and a common rating system for sustainable building.

2.1 Green Building

Green building is a "high-performance property that considers and reduces its impact on the environment and human health" (Yudelson, 2008, p. 13). It is designed to be one part of the answer to the global issue of energy consumption and waste production by reducing energy and water use as well as green house gas emissions. This can be achieved through every stage of building from siting, design, material selection to the actual construction and operation of green building. Green building requires increased planning and organization as the selection of materials and operation systems may affect the building schedule and require further knowledge and equipment on the part of the contractors. A sustainable green building must account for resources and local climate factors and include low-impact materials as well as energy and water efficient systems. The construction of green buildings reduces on-site waste by recycling and conserves natural resources by using alternative materials. Green building achieves better operating performance with better insulation, design, and energy efficiency. Green building efficient Heating, Ventilation, and Air Conditioning (HVAC) systems provide better air and a healthier environment for the people who live in one of these buildings.

In order to easily provide green information and guidance for people to go green, a common rating system to measure and compare the performance of green building is necessary. The main rating system that was developed in the US and is currently used widely is the LEED rating system.

2.1.1 LEED Rating System

The Leadership in Energy and Environmental Design (LEED) rating system, launched in the year 2000 by the U.S Green Building Council (USGBC, 2008a), is a point-based system used to define and rate performance of green buildings. Although it is a relatively new system, it has been adopted by 18 states and 59 cities, along with some designers, architects and building owners.

There are currently 4 levels of certification: Certified, Silver, Gold and Platinum (USGBC, 2008b). Each level represents the degree of sustainability a building can achieve with Platinum is the highest level. In LEED system, a building is rated on five key elements: Sustainable Sites, Water Efficiency, Energy & Atmosphere, Material & Resources, Indoor Environmental Quality and Innovation & Design Process. The better these elements are addressed in a building, the higher the rating. The points given to each element are varied from the type of building such as commercial or residential and also from the state of building such as existing renovation or new construction. Table 2-1 shows an example of detailed points given to each element in the LEED Certification for New Construction. For new construction, the points needed to achieve different level of certification are: Certified (26-32), Silver (33-38), Gold (39-51), Platinum (52-69).

Table 2-1: Detailed LEED Points for New Construction

Categories	Points
Sustainable Sites	14
Water Efficiency	5
Energy Atmosphere	17
Material & Resources	13
Indoor Environmental Quality	15
Design Process	5
Total	**69**

The LEED's point based rating system is not yet complete and currently has many unsolved gaps such as the balance of points given has not fully address all different aspects of green building. Currently, the USGBC is examining its point system to further improve it and to prevent builders from "point grubbing", a phenomenon mentioned by Mr. Ken Sandler, a USGBC research committee member (Refer to Appendix F for detailed interview). Currently, some builders seek higher rating system by using any cheap and not necessary effective methods to achieve the required number of points for the rating. The USGBC also recognizes that the LEED rating system needs to be more than just site specific. The USGBC is preparing to update their rating system with climatic consideration where the rating system points will be varied between different regions. These points will be weighted on the feasibility of implementing the green technologies with different geographic and climatic consideration.

Another new direction in the LEED rating system is its developing program called LEED Neighborhood Development, better known as LEED-ND (USGBC, 2008b). This program is aimed primarily towards new development in the residential market on a large scale. It promotes smart growth, new urbanism, and green buildings. Currently the program is only in a pilot stage, but it is expected to be adopted as a standard in late 2009.

Beginning in 2007, all new commercial buildings certified by the LEED are required to reduce carbon emissions by 50% compared to current emissions level (USGBC, 2008a). The reduction can be achieved by looking at all four categories that can lessen a building' carbon footprint: energy, water, transportation and materials. The USGBC also set two main goals to significantly push green building forward. By the end of the year 2010, the US aims to achieve 100,000 LEED-certified buildings and 1 million LEED-certified homes. The USGBC is also working with other groups such as the American Institute of Architects in order to reach these goals by developing professional training and new evaluation software for the design and construction of new green buildings. As of 2008, there are 15,609 LEED certified buildings around the nation. The detailed trend of LEED development is shown in Figure 2-1.

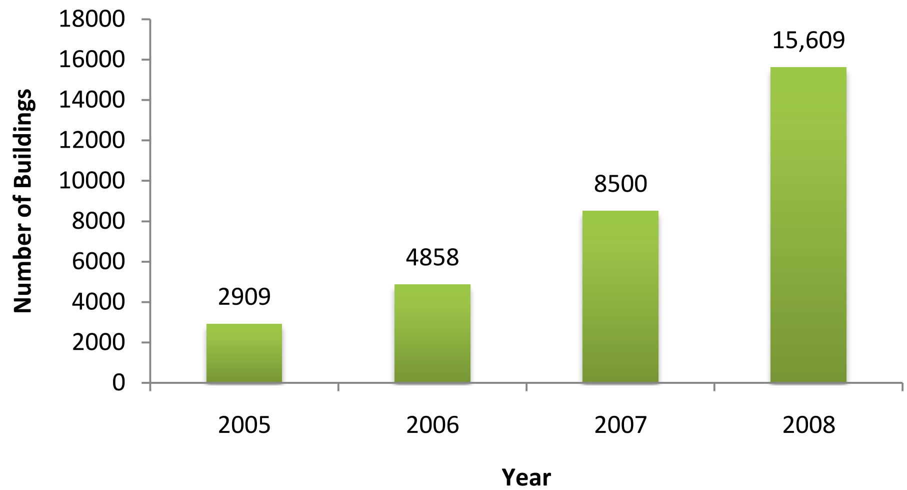


Figure 2-1: Number of LEED Certified Buildings Increasing Trend (USGBC, 2008a)

Other than the LEED rating system, there are also other rating systems for green building such as the Green Globes system, which was created by the Green Building Initiative nonprofit group (Yudelson, 2008). The Green Globes system is a web-based system that has been adopted by 6 states thus far. Although it is virtually identical to the LEED system, addressing at least 85% of the same concerns, the Green Globes system is much less popular now compared with the LEED.

2.1.2 Benefits and Costs of Green Building

Green commercial buildings experience numerous economic and productivity benefits (Yudelson, 2008). Some of the economic benefits include reduced operating and maintenance costs, increased building value, tax benefits and increased employee productivity. The operating and maintenance costs are reduced thanks to the energy savings, which could be 25 to 40% more efficient than traditional buildings. With these savings, the building's value is greatly increased, which can offer the owner a return rate of 20% or more. A LEED Gold certified building in California is estimated to save approximately $500,000 a year in energy costs. The energy cost savings offered by green buildings has prompted governments to start considering offering tax benefits such as tax credits and property and sales tax abatements to promote people to start using green building.

Green building also affects the productivity of employees in the building. For example, high-performance lighting increases the productivity by approximately three percent.

There are many more benefits of green buildings such as health and public relations. However, a lot of people believe that the cost of green buildings is still relatively high. While it is true that green buildings often cost from 1% to 5% more than traditional buildings, the benefits obtained can make up the difference (Yudelson, 2008). The lower operation cost could potentially pay back for the cost of the building in a few years of the building cycle. A homeowner who uses green technologies could also obtain similar benefits due to increased property value, water conservations and energy savings, especially by reducing heating and cooling costs.

Considering the benefits a green building can offer, the cost of going green is worth the investment. Because of people's perception of green buildings as being expensive, one of the most important research areas in green building is how to reduce costs (USGBC, 2008b). As mentioned in previous section, green building typically costs from 1% to 5% more than traditional building. For example, a $5 million project ends up costing $1 million more if LEED certification is sought. In order to make the adoption of green building more mainstream, it is necessary to reduce the cost of green building technologies. Many agencies including the U.S. EPA are starting to allocate funds for research to make green building more affordable.

2.2 Water and Wastewater Infrastructure

Wastewater infrastructure and green buildings affect each other. Green building can reduce negative impacts on water infrastructure by improving water efficiency using different sustainable methods such as recycling water for flushing toilets. This section describes water supply hydrological cycles, wastewater infrastructure, water reuse and stormwater management.

2.2.1 Water supply cycle

Water supply hydrological cycle addresses the impacts of buildings in the cycle of obtaining potable water. Water is important for everyday human activities including drinking, cooking, and cleaning. In the United States, buildings account for 13% of potable water consumption, approximately 15 trillion gallons annually (USGBC, 2008a). According to the EPA (2004), if this water usage trend is continued, many states will have fresh water shortages in 30 years. Once water has been used, it is released back into the environment. Untreated water can pollute and cause negative impacts on the environment and humans. Therefore, it is necessary to improve the efficiency of water usage as well as to reduce the impact of wastewater on the environment. Every day, water flows from natural sources to supply human activities and then is returned back to rivers and seas. We call this cycle the "water supply cycle" to differentiate it from the ecological water cycle, which describes water flow in nature. An illustration of the water supply cycle is shown in the Figure 2-2. The chart was created using materials from the EPA website (2008).

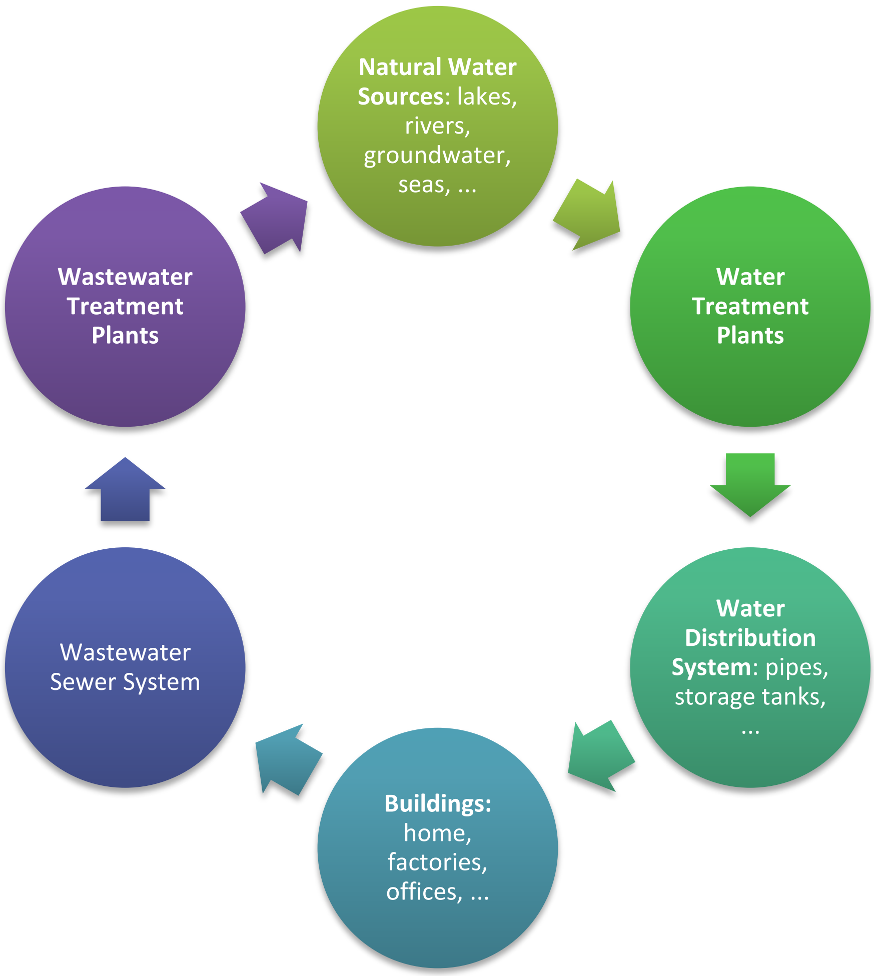


Figure 2-2: Water supply cycle of current potable water system in the U.S.

The water supply can come from many different sources such as rivers, lakes, aquifers, and oceans. Although oceans cover most of the global surface, this source of water is not commonly used because it must go through a desalination process, which is often too costly and inefficient compared with other water sources. In the US, the majority of the potable water comes from surface and groundwater sources. Before any water is used, it has to be treated and purified at a treatment plant to prevent any harmful effects to human health. The treatment standard is defined strictly by the Safe Drinking Water Act (SDWA) (Further information of the SDWA can be found in Appendix). After treatment, the potable water is supplied from the treatment plants to buildings through a distribution piping system.

In the buildings, water is used in a variety of ways. There are two types of wastewater generated from these uses: grey water and black water (Ludwig, 2006). The wastewater created by activities such as cooking, cleaning, and washing is called grey water. Grey wastewater often contains chemical substances and food wastes. It accounts for about 50-80% of wastewater generated by households. The other type of wastewater is black water, which is water that was used to flush toilets. Black water is often more contaminated and needs further treatment.

In addition to wastewater created by residential buildings, manufacturers produce a large amount of wastewater. According to Billatos and Basaly (1997), the United States manufacturers generated 6.5 billion tons of wastewater in 1986. This type of wastewater often contains of oil, sludge, ash, and other waste products and is mostly generated by the cleaning process. The wastewater from manufacturing processes needs special treatment depending on the industry (US EPA, 1995). This wastewater treatment process is regulated by the EPA and controlled under strict standards using best management practices.

The wastewater is transferred to wastewater treatment plants municipal sewer systems. At the wastewater treatment plant, the water is treated to remove all toxins, wastes, and chemical substances that can be harmful to the environment. After treatment, water can be returned to other sources.

2.2.2 Wastewater infrastructure systems

Supply is only a piece of the water cycle; after potable water has been used it enters the wastewater infrastructure system. The scale of wastewater treatment and discharge in a community depends on its size. The wastewater treatment systems in the United States face a lot of challenges, from the vast scale and large area of the country to the increasing population and demand for better water quality.

Increasing population brings a need to continuously upgrade the current water infrastructure system. According to a survey in 1995, the capacity of United States wastewater treatment facilities was for 190 million people, which was only 73% of the total population (US EPA, 1995). The rest of the wastewater was treated using septic systems. The EPA plans to expand and increase the number facilities to meet all the needs of the population. Estimates from the EPA show that an increase from 16,000 to 18,000 facilities by 2016 will be able to provide services for 90% of the population.

However, in order to build such a large number of treatment plants, there is a need for significant financial support from the government. Development in a large country like this is a very costly and difficult objective (Grigg, 2003). Since the current income of the water infrastructure system is mainly from the water bills paid by customers every month. This amount is hardly enough to cover the cost of operating and maintaining the facilities. Therefore, financial assistance from the government would be necessary to cover these costs. From a survey of wastewater facilities regarding funds required, the EPA has estimated that it would take 140 billion dollars to replace and improve current systems in order to fill the gap. The details of this amount are categorized as shown in Figure 2-3.

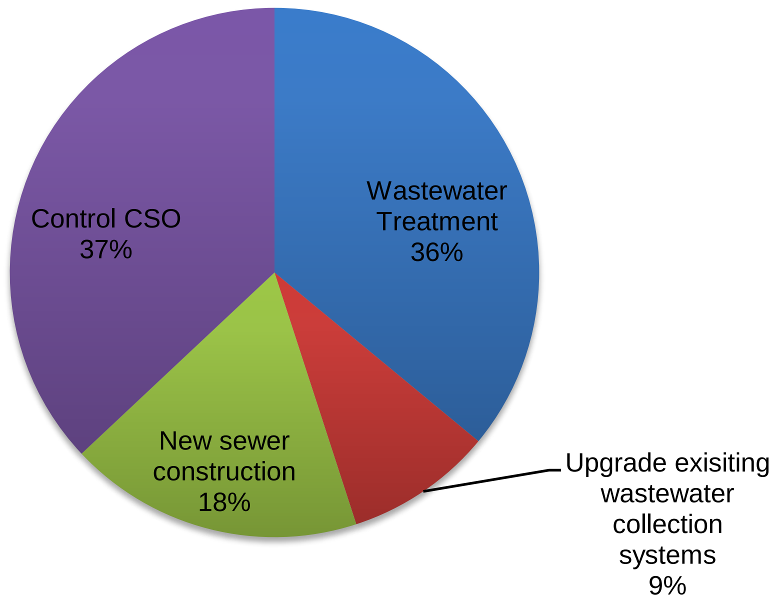


Figure 2-3: Budget needs for wastewater facilities by percent of total budget (Grigg, 2003)

2.2.3 Building's impact on water infrastructure systems

The construction and operation of buildings have large impacts on the aging water infrastructure systems in the US and also on the environment.

For the environment, buildings' impervious surfaces including rooves, pavement, parking areas and roads divert rainwater from the site location into stream, rivers, ponds, lakes, ... It prevents the rainwater from evaporating into the atmosphere and seeping into the ground. Therefore, it reduces the amount of natural recharge and replenishment of water sources including both surface and underground water in these areas. Also, the construction of buildings at some sites, especially near a wetland, can cause some dramatic changes to the aquatic habits of the surrounding area, thus disrupting the ecological balance.

To the water infrastructure system, buildings directly discharge wastewater from potable and non-potable uses into the municipal sewer system. The building's impermeable exteriors also cause stormwater runoff that largely contributes to land erosion and combined sewer overflow (CSO) during peak rain fall periods.

Besides all its direct impacts, building operations also have many indirect impacts on the water infrastructure systems. The water distribution system uses energy to deliver potable water from water sources to building sites. In many regions where water sources and water treatment plants are very far from the community areas, this delivery cost is very significant. Transferring and treatment of wastewater from buildings also consumes a large amount of energy and money.

2.2.4 Wastewater

In the United States buildings account for 13% of the potable water used. This proportion is higher than any other country (EPA Office of Water, 2008). The domestic use of water can go as high as 165 gallons per building per day, which puts significant stress on the water infrastructure system. There are two types of wastewater generated by activities at buildings: grey water and black water. Black water is wastewater used from flushing the toilets while grey water is wastewater generated by other activities such as washing, cleaning, showering, etc. Table 2-2 describes detailed usage of water at 3 different main types of building: homes, offices and hotels.

Table 2-2: Typical Domestic Daily per Capita Water Use

	Home	Office Building	Hotels
Potable Indoor			
Shower	7.80%	--	27.00%
Kitchens	0.60%	3.00%	10.00%
Faucets	6.60%	1.00%	1.00%
Other uses, leaks	6.70%	10.00%	19.00%
Subtotal	**21.70%**	**14.00%**	**57.00%**
Non-potable indoor			
Laundry	9.10%	--	14.00%
Toilet	11.20%	25.00%	9.00%
Cooling	--	23.00%	10.00%
Subtotal	**20.30%**	**48.00%**	**33.00%**
Outdoor			
Subtotal	**58.00%**	**38.00%**	**10.00%**

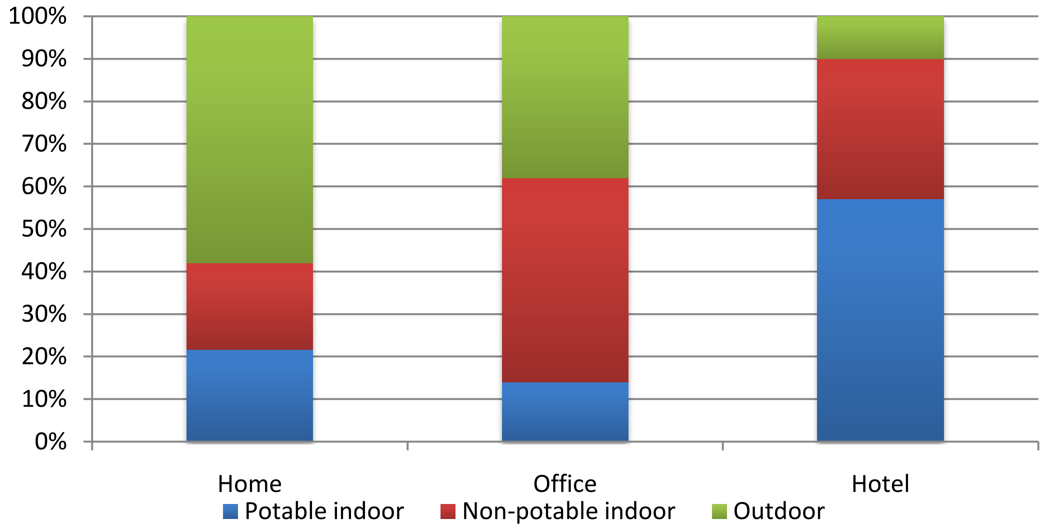


Figure 2-4: Typical daily water use per capita (EPA Office of Water, 2008)

As shown from the Figure 2-4 above, 80% of potable water used at home is not for potable purpose. Rather, it is used for flushing toilets, landscaping and other non-potable uses. The same problem happens for water uses at office where the amount of potable water that is actually used for potable purpose is less than 15%. At hotel, potable water uses for non-potable purpose is still more than 40%. Potable water is highly treated drinkable water delivered to buildings according to the Clean Water Act. Therefore, the use of potable water for non-potable uses such as flushing toilet or landscaping is highly inefficient as lower quality water can be used for these purposes.

In the United States, grey and black water share the same sewer system, which requires the sewer wastewater to be highly treated at the level of black water. However, according to Ludwig (2006), this practice is inefficient since grey water does not contain any illness-causing substances given there are no documented cases existing in the US ascribing transmitted illness to grey water. The treatment involved in treating wastewater is less intense than treatment for black water since there is less contamination such as pathogens and nitrogens involved.

Grey water chemicals and wastes can be effectively absorbed and filtered by the soil and trees (Ludwig, 2006). The top layer of soil is very efficient in purifying the grey water before it reaches deeper layers, which can be even more effective than a treatment plant, thus protecting the underground water and even surface water. Therefore, a wetland can be an effective filter layer. A constructed wetland is an efficient way to reduce most of the wastes contained in grey and even black water. Sidwell Friends Middle Sschool is a LEED Platinum certified facility which uses wetland technology. Their wastewater recycling techniques allow them to achieve 93% water efficiency. Their recycled grey water is of high enough quality to use for non-potable purposes in the building such as flushing toilets and irrigation. Reducing the amount of grey water discharged into in the municipal sewer systems also relieves the stress for the treatment facilities. Less waste flow means the treatment plants treat more effectively and at a reduced expense.

However, more research should be performed on the reusability of grey water to prevent any negative impacts on public health. The Uniform Plumbing Code (UPC) and International Plumbing Code (IPC) set treatment standards for grey water reuse in water closets and irrigation. They also require a labeling system to notify a user that the water is reclaimed. The current legal system is very strict and costly on allowing grey water reuse, which often discourages people who are trying to implement such a system. Rain water is another potential source for water reuse. However, since there is no differentiation between rain water and grey water, they are unnecessarily required to undergo the same treatment, hindering the reuse of rain water. The grey water has to go through a filtration process before being used in irrigation or being recycled. A grey water recycling model is shown in Figure 2-5.

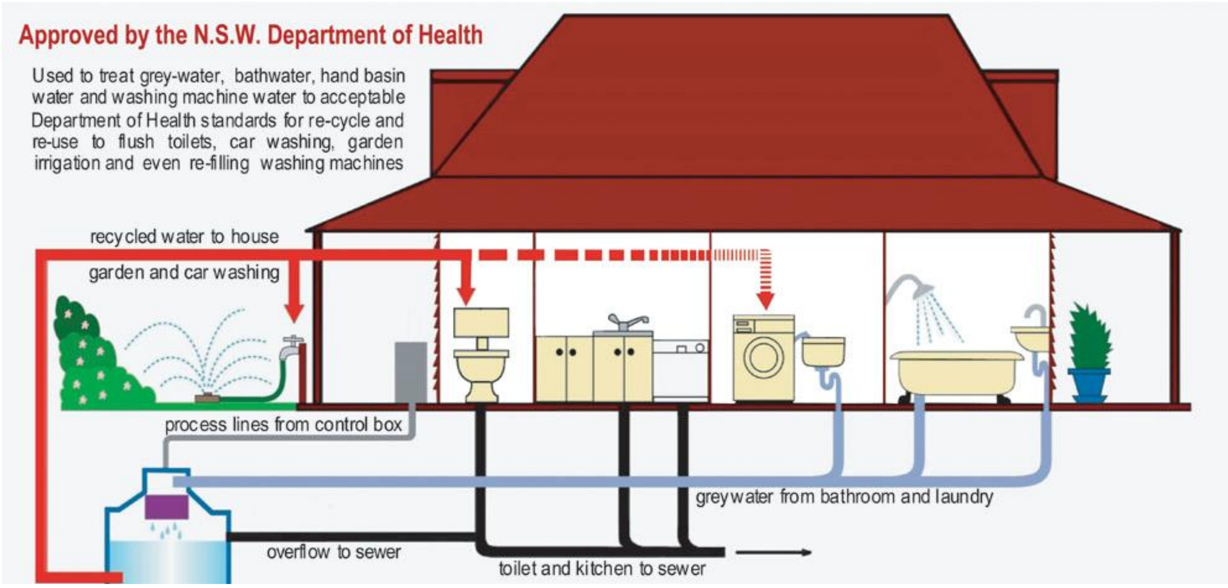


Figure 2-5: Residential grey water recycling model (EPA, 2006)

2.2.5 Water Efficiency

Water efficiency is one important aspect in green building. When the building water consumption decreases, so does the amount of wastewater released. Water efficiency can be achieved through many different things: more efficient home appliances such as toilet, shower, and faucets; human attitude; and reuse water.

The EPA has program WaterSense dedicated for water efficiency products (US EPA, 2008a). This program is to provide standard and promote water efficient products. There are many products that we can change at our home without alternate our normal lifestyle. We have waste so much water in everyday activities such as letting the faucets running without using or landscaping the house lawn. With more efficient products, the water usage can be reduced to minimum while we can still do the same job effectively. By replacing old products with WaterSense ones, billions of water can be saved every day.

WaterSense faucets, if used in every home in the US, can save 60 billion gallons of water annually, which makes them 30% more efficient without sacrificing performance (US EPA, 2008c). By implementing landscape irrigation equipment that is 15% more efficient than a typical device, 1.5 billion gallons could be saved per day. If low-flow toilets and urinals were implemented throughout the country two billion gallons of water per day could be saved across the country.

Society's awareness of water efficiency must be improved if large scale reduction is desired. Most of people know that we can save as much as 3,000 gallons per year just by turning off the faucets while brushing our teeth. However, not all of us do. People awareness is an important factor affecting water use efficiency. No matter how efficient the product is, it is still wasteful if the person using it does not recognize the importance of water.

2.3 Stormwater Infrastructure

While grey and black water are necessary considerations for green building, another essential aspect is stormwater management. Stormwater runoff has been a problem that conventional building has paid less attention to. During precipitation, water runs from rooftops onto lawns and/or streets. The water then carries along all the chemicals, pesticides, wastes, and any other contaminants it comes across. The water ultimately flows into the municipal sewer systems or into natural waterways (Coffman & Clar, 2003). This problem is often worse in urban regions where most of the surface area is covered by impervious surfaces such as roads, construction, and parkways. Figure 2-6 illustrates the stormwater problem and its potential impacts. Once water is collected from a large area, it can potentially cause flooding. When the sewer systems capacity is exceeded, which is called Combined Sewer Overflow (CSO), it typically causes erosion to the lands outside of urban area. The overflow of sewers can release raw sewage to the environment before it reaches the treatment plant. In the US, many cities have attempted to reduce CSO by separating combined sewer pipes with stormwater pipes and expanding treatment and storage capacity. In areas where more development occurs with impervious surfaces, larger size piping system will also be required. However, these practices are very expensive and will take decades to fully develop.

Figure 2-6: Stormwater runoff model (EPA, 2006)

2.3.1 Green Roof

There are many different onsite methods that can reduce the impact of the stormwater effectively. A popular technique used with green buildings is the eco-roof, better known as a green roof. According to Worcester Polytechnic Institute's (WPI) Professor Paul Mathisen, who is currently responsible for monitoring the water quality and efficiency of the green roof at the recently built green building residence hall at WPI, the green roof is one of the most effective methods to manage stormwater runoff in a building (detailed interview can be found in Appendix C). A green roof typically achieves water retention rates from 60-80%. However, this number can be deceiving. In the summer months and during periods of little rainfall a green roof can achieve up to 100% water absorption. In periods of heavy rainfall a green roof cannot prevent stormwater runoff but rather gradually releases the water later to prevent overflow in sewer systems. The green roof also acts as a layer to filter some chemicals out of the water. It can naturalize the radiation from the sun, thus making an effective insulation layer, which retains heat in the winter and cools the building in the summer. This can lead to a large saving on energy costs.

Figure 2-7: An example of green roof

Even though a green roof is beneficial and not very complicated to implement, the US has only recently begun to adopt this technology. According to a study done in Portland, Oregon, costs range from $10 to $15 per square foot for new construction and $15 to $25 per square foot for re-roofing (Environmental Services City of Portland, 2006). A green roof garden typically lasts twice as long, 40 years, as a traditional roof with little to no maintenance (Fox, 2008). Germany, which started the trend in the 1950s, has been the leading country in the world since then in promoting and building green rooves. There were 50 square miles of green roof built in Germany in 2006, compared with the estimated area of 0.143 square miles, in the United States in 2008. This area, considering the number of buildings in the United States, is insignificant. However, the growth rate of green rooves in America has increased steadily in the last 3 years. According to surveys from the *Green roofs for Healthy Cities* (2008) from 2005 to 2008, the green roof growth area has been steady at 900,000 square feet per year. Figure 2-8 illustrates this trend. The graph was made using the data from the surveys of *Green roofs for Healthy Cities*.

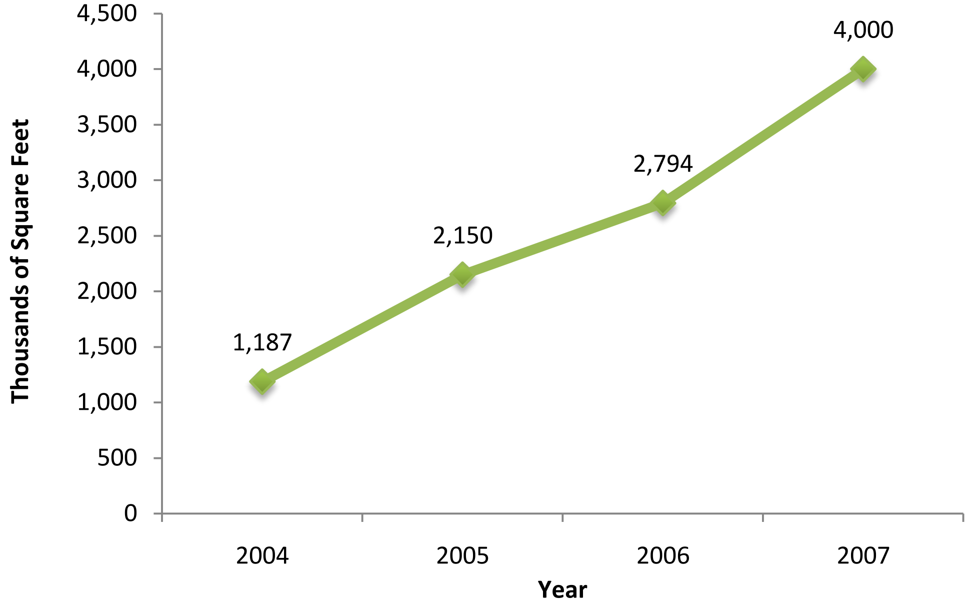
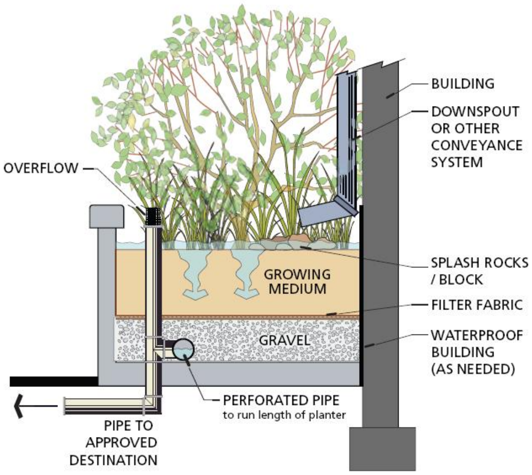


Figure 2-8: Trend of Green Roof (Green Builder, 2008)

2.3.2 Other Stormwater Management Methods

In addition to green roofs there are other methods for stormwater management using low impact development practices. As mentioned previously a green roof's vegetation and soil can filter stormwater. This same principal can be applied to ground level flora as well. Portland, Oregon, is an example of location with a citywide initiative to adopt green practices in an effort to reduce and eliminate stormwater runoff. They have implemented a myriad of innovative methods using vegetation and collection (Figure 2-10). One such method is the rain barrel (Figure 2-9). This involves directing the rainwater gutters into drums where the rainwater is then held until it is used for non-potable sources such as irrigation.

Figure 2-9: Rain barrel (Environmental Services City of Portland, 2006)



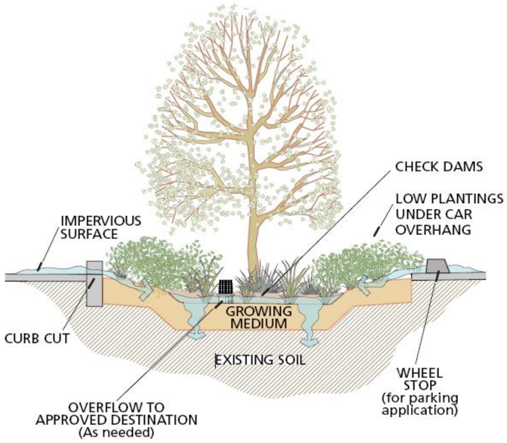


Figure 2-10: Vegetation to manage stormwater (Environmental Services City of Portland, 2006)

2.3.3 Stormwater Materials

As has been mentioned previously, impervious pavement promotes stormwater runoff. This has led to the development of pervious paving materials. There are two types of pervious pavement: pervious pavers and pervious pavement. Pervious pavers resemble traditional bricks or walking stones while pervious pavement can resemble either asphalt or concrete. These materials are designed with pores, allowing water to filter through into the ground rather than runoff across the surface. As seen below in Figure 2-11 the pavement or pavers is a rock base that further promotes water flow through the surface.

Figure 2-11: Pervious pavement (Environmental Services City of Portland, 2006)

It is very costly to implement stormwater management practices and provide maintenance to current systems. Stormwater research currently does not receive enough funding and attention (Grigg, 2003). Financial support is needed to improve the aging stormwater infrastructure, which needs inspection and continuous maintenance (Coffman & Clar, 2003). According to a survey from the USGBC (USGBC, 2008a), stormwater management research only received $1.2 million of funding between 2002 and 2006, which is less than 1.7% of the total funding for green building related research. Funding is necessary to improve the efficiency of current stormwater management methods because most conventional practices are not efficient enough to meet the current complex environmental objectives.

2.4 Social Acceptance and Adoption of Green Building

As energy costs and living expenses increase, more people are turning to more efficient and cost effective technologies such as green buildings (Boutwell, 2008). As discussed above, green buildings have many benefits such as energy efficiency. However, while green building awareness is increasing, many people are still unaware of the various benefits. Although an effort is being made to increase the knowledge and use of green building and sustainable technologies, the adoption of these technologies in the building industry is still on a limited scale.

To determine the social acceptance of green buildings, it is best to determine the "three dimensions of social acceptance … socio-political acceptance, community acceptance and market acceptance" (Wüstenhagen, Wolsink, & Bürer, 2007). Socio-political acceptance can be measured by polls and surveys to determine a general opinion of green buildings. The broad majority of people support the idea of renewable and sustainable technologies such as green buildings. However, while most people do support the idea of green buildings, they have been reluctant to adopt them.

There is a correlation between the slow pace of green technology adoption and community acceptance (Wüstenhagen, Wolsink, & Bürer, 2007). Community acceptance of green buildings is best showcased by the level of approval by residents, local authorities and other local stakeholders in a community. In some cases, communities may be more socio-politically accepting of the idea of using sustainable technologies until asked to implement the idea in their community. Other cases show the reverse of this case in that communities are reluctant to accept sustainable technologies until a time occurs to adopt them in their community such as converting a local community center into a more environmentally friendly building. These cases are usually a result of lack of education about green technologies, which has led people to believe that the technology is difficult to implement or extremely expensive.

This lack of knowledge about green buildings is especially important to deal with if market acceptance is to be achieved. Market acceptance calls for a demand for the technology by both consumers and investors. While most of them are aware that green buildings have many benefits, many do not have a full understanding of the actual benefits. In a recent survey conducted by the Washington Department of Ecology (ECY, 2008), at least 22% of those interviewed were unaware of an energy efficiency difference between green and non-green built homes, and 31% of those interviewed were unaware of any water conservation benefits. However, the broad majority of people support the idea of renewable and sustainable technologies such as those found in green buildings. Many people also believe that the implementation of the technology is often difficult or expensive (Wüstenhagen, Wolsink, & Bürer, 2007). Most of these technologies that have not made mainstream advertisements, unlike EnergyStar products like dishwashers, are thought to be too expensive to implement by the average person building a family home. Investors, on the other hand, recognize that most green technologies are being marketed in the wrong way, which focuses not on consumer need but rather the "greenness" of the technology.

To increase acceptance of green building technologies, different organizations and states, such as Florida, are promoting green buildings in an effort to curtail energy and water costs (Florida Solar Energy Center (FSEC), 2008). The FSEC has outlined a "Green Building Public Awareness Campaign Plan" in order to bring awareness of the advantages of building better, more environmentally friendly homes. This plan calls for surveys, media and community relations, web site development and advertising. The surveys are used to determine how many people in Florida know about the advantages of green homes. Media relations and advertising will be used to educate people about green homes. As more states advocate environmentally friendly technologies, more people will become aware of green building. This will lead to a bigger market for green building technologies as well as more efficient homes.

The concept and benefits of green buildings is undisputable (Lockwood, 2008). Green factories can be very beneficial as a result of their practices: "they use less energy and water, have lower greenhouse gas emissions, and provide a healthier work environment than conventional buildings" (p. 52). But in the United States, most of the green buildings constructed over the past decade have been primarily white-collar workplaces, including office buildings, schools, and R&D

facilities. The adoption of green technologies in blue-collar workplaces, from warehouses to distribution centers to factories, has lagged far behind.

Although the number of green workplaces built in 2007 is still relatively small, the trajectory has matched the rate of increase of white-collar buildings over the past eight years as shown in Figure 2-12 (Lockwood, 2008). This trajectory increase was slow in 2000 but has improved steadily through 2007. Only 46 white-collar green buildings registered for or received LEED certification in 2000, when it first became available. The number has increased dramatically from 1,632 buildings in 2006 to 5,417 in 2007, a 232% increase in one year. Similarly, the number of blue-collar buildings in 2007 climbed to 111, a 178% increase (See Figure 2-13).

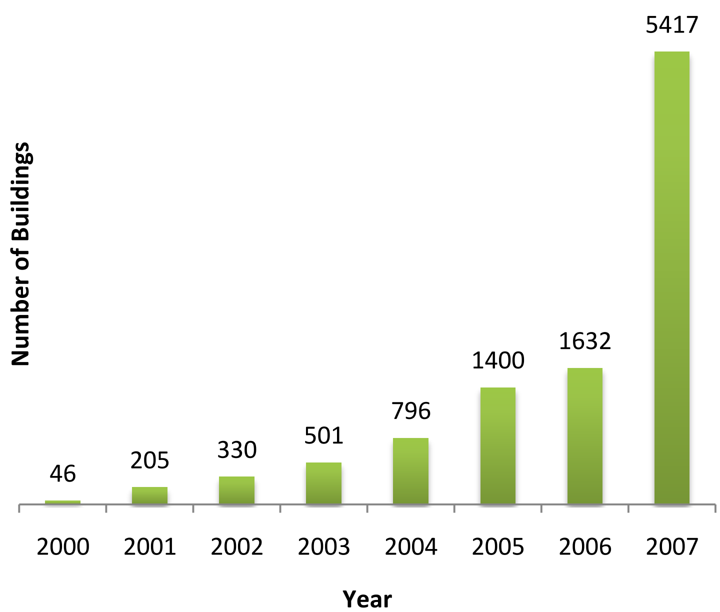


Figure 2-12: Number of Commercial LEED Certified Buildings (Lockwood, 2008)

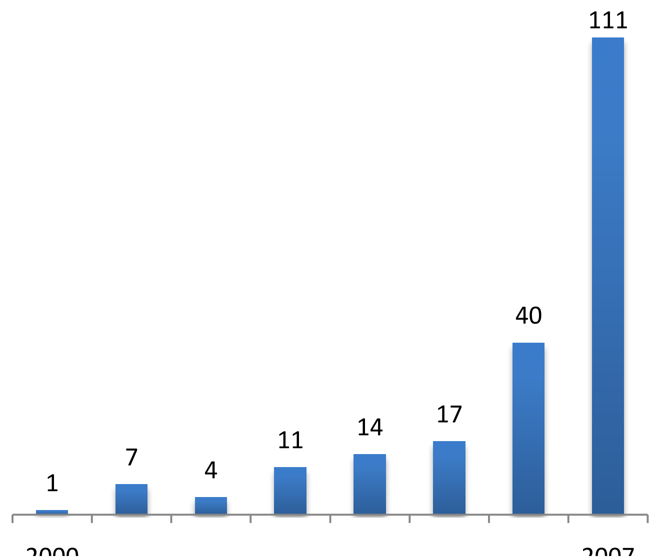


Figure 2-13: Number of blue-collar buildings built (Lockwood, 2008)

2.5 Conclusion

As shown above, green buildings have the potential of reducing the effects of green house emissions and making our environment better. This chapter provided background information to understand the analysis in this report.

3 Methodology

The NCER is the lead provider of extramural research and development for the EPA. This office is in charge of providing research funding to academic institutions, independent companies, and organizations. Since there is not yet a designated strategy for green building research, the NCER's past research has been scattered and without focus. Green building research will be of great value in the future as the EPA moves toward developing and promoting sustainability. Of the various impacts that green building has on the environment, our project concentrated specifically on the impacts that green building has on the water and wastewater infrastructure systems.

Our goal was to provide recommendations to NCER, specifically prioritizing areas and technologies in need of future research. We focused primarily on wastewater treatment, water recycling and stormwater management. We developed the following list of 4 objectives to achieve our goal.

- Identify and organize all current and past research sponsored by NCER related to green buildings.
- Identify current and past research sponsored by other offices within the EPA and by other organizations on green building.
- Analyze and identify the gaps in research and technologies with a focus on water infrastructure.
- Determine the EPA's budget and regulatory constraints to carry out research to provide appropriate recommendations.

Significant research has been accomplished regarding green buildings and related technologies from different agencies and organizations. Identifying these resources gave us an understanding of the current direction of green building research. To have a complete view of water infrastructure research we looked at projects from sources within and outside of the NCER.

When looking at sources from within the EPA, we faced several challenges when gathering the information. As an agency, the EPA is set up in a matrix where each office does research in its specific field, for example, the office of water is dedicated solely to water. Given that green building is a new area of research there was no strategic goal or budget dedicated to green buildings. Therefore each of the different offices within the EPA carries out research related to green building that fit its specific mission. This creates research that does not typically focus on green buildings per se, but instead addresses different technologies that could be implemented in green buildings. Therefore, the research was scattered in different categories such as alternative energy, pollution prevention, air quality, wastewater treatment, etc. Our first search for information came from NCER's archive, where our project was based. We then studied what other EPA offices as well as other organizations had done.

3.1 NCER's green building research

We began our search for past research with NCER's electronic database system. Their archive contains every funded project since 1995, which approximates to 5500 projects. These projects fall under different NCER programs: Science To Achieve Research (STAR), Small Business Innovation Research (SBIR), People, Prosperity and Planet (P3), Collaborative Science and Technology Network for Sustainability (CNS), etc. To avoid ambiguity and confusion, we developed a list of categories that provided a clear definition of what type of green building projects we were searching for (Refer to Table 3-1 for a detailed categories list). In order to validate if a project fit into our categories we looked at the *Abstract* of each project. If a report's *Abstract* was inadequate to determine then we went on to the *Project Description*.

Table 3-1: Detailed categories used to classify NCER's project

	Categories	Details
Scale	**Site Specific**	The project is related to the design of a single building
	Commercial	Schools, offices, large apartment complexes, etc.
	Residential	Single houses and small apartment buildings
	Regional	The project is related to large scale planning such as a region or a community.
	General	The project can be implemented everywhere.
Media	**Multimedia**	The project considers 3 or more aspects of green building media.
	Wastewater	The project is related to the treatment or reuse of wastewater generated from construction or operation of a building.
	Reuse	The wastewater is treated and reused.
	Pretreatment	The wastewater is pre-treated before disposal to municipal system.
	Stormwater	The project is related to stormwater management practices or stormwater treatment.
	Green roof	The project is related to designing, improving, or maintaining ecology roof used for stormwater management.
	Watershed	The project is related to urban planning and stormwater management into local reservoirs or ponds in order to treat stormwater from a large area.
	Others	The project is related to other stormwater management practices such as rain barrels, rain gardens, pervious pavements, etc.
	Water efficiency	The project is related to improving the efficiency of water usage while maintaining the effective performance.
	Energy efficiency	The project is related to improving the efficiency of electricity, heating or using alternative energy such as wind and solar energy.
	Material	The project is related to the use of green materials in construction or the reuse of waste material from demolition.
	Indoor Air	The project is related to the improvement of ventilation and indoor air flow within a green building
Approach	**Planning**	The project is related to sustainability planning of a region and a community, not specifically related to green building.
	Technologies	The project is related to developing or improving technical aspects of a green building e.g. stormwater control devices.
	Metrics	The project is related to the development of metrics or methods to monitor performance.
	Implementation	The project is related to the design or implementation of green practices
	Social Acceptance	The project is related to educating consumers on green building practices

After we identified all the green building related projects, from the 5500 total in the NCER's database, we classified each project into categories of different 3 dimensions: *Scale*, *Media*, and *Approach*. In each dimensions, we developed various categories to address different green building of a project regarding green building technologies. The *Scale* dimension is to distinguish between the sizes of implementation of a project. A project can aim at a *Site Specific* single building, a large *Regional* building planning or just *General* technology. Within *Site Specific,* we also distinguished between *Residential* and *Commercial* sectors in order to have better view on the type of location of green building. The *Media* dimension includes all different types of green building research field that a project can fall into: *Stormwater, Wastewater, Energy Efficiency,* etc. Since our project's focus is on water infrastructure, we developed further sub categories in two main areas of water infrastructure: *Stormwater* and *Wastewater*. Details of each category can be found in Table 3-1.

With input from our liaisons, we chose several key projects related to green buildings or associated technologies to further investigate. These projects were chosen from the three main funding programs, CNS, SBIR and P3, because each program has a different strategic goal and aims to support different types of research. We retrieved physical copies of these reports and analyzed the technology researched. We then compared these technologies with our background research and consulted with our liaisons about the feasibility of these technologies. We set up interviews with the Principle Investigators (PI) by phone or email to further evaluate each project. We developed a common interview protocol for these interviews with a script and standardized questions (Refer to Appendix E). The information desired from the interviews was details of their results and any lingering questions they had after the completion of the project. We always finished by asking for input and opinion regarding research gaps of green building technologies.

3.2 External NCER's green building research

While our project is based within NCER it was essential for us to consider green building research completed by other offices within EPA and also other organizations. By looking broadly we were able to identify if any of the gaps that exist in NCER's research had been filled by other sources.

3.2.1 Other EPA Offices' green building research

Within the EPA, several other offices have also been working on developing or implementing green building technologies. Therefore we gathered information from these offices about their past and current projects to ensure our suggestions to NCER do not overlap with what is already being done elsewhere within the EPA. We also held interviews with employees from each of these offices to further clarify their purpose and gather their opinions regarding future research areas. We also wanted to look at the progress of different green EPA programs, such as WaterSense.

The Office of Wetlands, Oceans, and Watersheds (OWOW) is in charge of stormwater management technologies. OWOW focuses primarily on reducing stormwater runoff through the implementation of simple green technologies, such as low impact development. We interviewed two employees, Ms. Abby Hall and Mr. Jamal Kadri, in this office to get an update on their current programs. Our objective of the interview with them was to gather their opinions on current stormwater management technologies, including green roofs, rain gardens and other methods. We also wanted to find out about their research budget and strategy for integrating these technologies with green building development.

For current green building programs in the EPA, we interviewed Ms. Alison Kinn from the Office of Pollution Prevention and Toxics (OPPT), and Mr. Ken Sandler from the Green Building Workgroup. Besides being the chair for the U.S. EPA Green Building Work Group, Mr. Ken Sandler is also a member of the Research Committee at the U.S. Green Building Council (USGBC), the organization providing the LEED Certification for green building. These individuals are in charge of providing a strategy for green building research, specifically evaluating a building's impacts on the environment and human health. From these interviews, we gathered ideas about the current challenges facing green building and what future programs the Green Building Workgroup is implementing.

We also interviewed Dr. Audrey Levine, the national director of the Drinking Water Research Program of the Office of Research and Development (ORD). She provided significant input on water infrastructure and how green building fits into the bigger picture. From this interview, we learned EPA's current direction on drinking water quality, water reuse, and water infrastructure.

Lastly, we interviewed with Ms. Stephanie Tanner of the WaterSense program, which is within EPA's Office of Water. This program focuses on the development and support of water efficient products that can be implemented within commercial and residential buildings to decrease their water usage. From this interview, we sought to identify any research needs for water efficiency in building and the impacts of green building on the larger water infrastructure.

3.2.2 Other organizations' green building research

Since the EPA's research strategy is from a regulation perspective, we also gathered feedback and opinions from other organizations to gain a broader perspective on green building strategies.

The U.S. Green Building Council (USGBC) is the organization that provides LEED certification for green buildings around the nation. We again interviewed with Mr. Ken Sandler of the Research Committee at the USGBC to discuss their future strategy. The planned improvements to the LEED rating system, as well as the current challenges facing green building research were our desired topics. We inquired about any data or statistics regarding the 21,000 LEED green buildings that the USGBC had certified. We also interviewed a Landscape Architect, Ms. Elizabeth Guthrie, from the American Society of Landscape Architects (ASLA) to learn of the challenges faced with designing green roofs, water retention and recycling systems.

We also visited several green buildings and green roofs to examine the technology implemented and to identify potential post occupancy problems of green building. We went to

Sidwell Friends Middle School, a school in the DC area that received Platinum LEED certification for their building. This was achieved as a result of the building's 93% water efficiency with wastewater recycling using a constructed wetland. At this site we concentrated on finding out if the buildings performance was being maintained after certification. Another green building we visited is the headquarter office of the USGBC, which also received Platinum LEED certification for their efficiency and environmental friendly material usage. We visited the green roof at ASLA's main office, where we concentrated on discovering any challenges in maintaining the roof, the benefits reaped, as well as any plans they had for implementing their green roof technology on a larger scale.

3.3 Identify Research Gaps

After collecting sufficient information on all the existing research pertaining to green building we began to visually organize it to allow for interpretation. All the aforementioned data collected, as described in section 3.1, was used to create charts and graphs to facilitate comparisons. We also conducted interviews with NCER employees, including Ms. Diana Bauer and Ms. April Richards, to obtain their opinions and feedback on the gaps we had identified.

3.3.1 Interpreting Past Research

Using the categories outlined in Table 3-1, we were able to analyze the 95 projects using different approaches. We looked at the funding trends by amount of dollars and in number of projects of different grant program in NCER. The programs that we included are *CNS, P3, SBIR*, and *Fellowship*. The rest of the projects that did not belong to any of these 4 programs were considered *Other*. We also looked at the funding trends of green building research from 1995 to present. From the trend we identified the programs that contributed most to green building research in order to better address our final recommendation. We also were able to identify the trend of green building research at NCER and project future research expectation. In order to identify research gaps, we plotted chart in the 3 dimensions categories that we mentioned in section 3.1. From the categories chart, we identified areas that had received insufficient funding. These data can be used by NCER in the as a reference of how they funded in green building related technologies.

3.3.2 NCER Interviews

To ensure the accuracy of our findings, we interviewed NCER employees from different programs. The purpose of these interviews was aimed at achieving agreement between their perspective and our identified gaps. We performed content analysis on the interview transcripts to identify the common gaps among the different interviewees. Using this analysis, we identified which gaps were most critical. We talked with Dr. Diana Bauer, the director of CNS program at NCER to discuss about the CNS projects. We also talked with Ms. April Richards about SBIR projects and its direction toward green building. For P3, we spoke with Ms. Cynthia Nolt Helm to gain a better understanding of the program.

Once we identified the gaps in research, we performed further background studies to strengthen our understanding in these areas. We performed studies on topics including water reuse and green roofs, which are technologies that we identified as receiving inadequate funding. We focused on the amount of research performed on these technologies to determine whether it was sufficient or required more attention. This helped us determine the impacts of each gap to have an appropriate evaluation before giving our final recommendations.

3.4 Determine focus areas

After identifying the research gaps, we determined which ones were research priorities for the EPA. We studied the mission statement and statutory regulations of NCER and the EPA, and the green building strategies of the various offices to determine which areas would be most appropriate for the EPA. We also studied the budgetary constraints of green building research and considered the cost of future research. We formed a list of research priorities that will serve as guidelines for the EPA in the future.

The main method for this objective was interviews. We interviewed employees within NCER as well as other EPA offices to gather their feedback on our priorities list. We returned to NCER director William Sanders. He provided feedback regarding the feasibility of the NCER providing research according to our recommendations. We sought to gain further insight into the constraints of the EPA regarding budget and human resources. We also interviewed Dr. Bauer and Mr. Gentry again because they were drafting the green building research strategy for the EPA. The interviews served to check if our recommendations fit in the mission and future direction of the EPA.

Ultimately, our methods sought to form effective recommendations for the NCER and the EPA. We aimed at maximizing research returns while considering their strategic goals regarding green building technologies. We tried to reduce bias and provide recommendations that would focus future research on improving green building technologies that would further reduce the negative impacts on the environment and human health.

4 Results and Analysis

To accomplish our goal of providing NCER with the most beneficial research recommendations, we utilized resources from both within and outside the agency to identify the existing gaps. Our results were obtained by accomplishing the following objectives:

- Identify and categorize all current and past research sponsored by NCER related to green buildings.
- Identify current and past green building research sponsored outside NCER, including sources within and outside of EPA.
- Identify the gaps in green building research and technologies with a focus on water infrastructure.
- Determine the EPA's budget and regulatory constraints to carry out research and provide appropriate recommendations.

By identifying and then categorizing 95 projects relevant to green building we discovered NCER's most prominent gaps in research are water reuse, water infrastructure, stormwater management practices, and the residential market. With the input of principle investigators and opinions from other offices within the EPA, we were further able to support our previously identified gaps. From our analysis of outside sources we concluded that an essential component to future research projects must be social acceptance. From our research studies and expert interviews we identified the best course for future research to follow. Analysis of these future research topics led us to develop two sets of recommendations for the NCER.

4.1 NCER Green Building Funded Research

We looked at each of the 5547 projects that the NCER has funded since 1995. After filtering out all the projects that did not deal with green building or related technologies, we were left with 95 different projects. To further compare and analyze these projects, we divided them into a set of categories addressing 3 different dimensions: scale, media, and approach. The list of categories can be found in Table 4-1. A detailed categorized list of the projects can be found in Appendix F.

Since there is no designated green building strategic agenda at NCER, many of the 95 projects that we chose to analyze do not deal directly with green building. However we included those projects if they focused on technologies that could potentially be implemented in a green building. Therefore, for some projects, the choice of whether or not to include them was ambiguous. The factor that influenced our decision was the level of practicality in implementing the research result. For example, the SBIR project "Stormwater Flow Control Device" dealt with creating a tool to measure and control the flow of stormwater. This project is explicitly related to water infrastructure, but not necessarily to green building. However, we included these types of projects in our green building project list because they could realistically become viable devices for use in green buildings in the future. The deciding criterion was that the projects are relevant to green building only if the method is currently used or being considered in the design of the building. Otherwise, we considered the project in its current state to be too distant from green building to be relevant.

The green building project list we chose has 95 projects, which made up less than 2% of the total number of projects funded by NCER since 1995. The grants to all 95 green building projects totaled $7.4 million, which is less than 1% of the NCER's overall funding in all areas. This small proportion of funded grants, both in term of dollars and number, are understandable because green building is a relatively new topic with no overall strategic direction. The projects' research areas are diversely distributed among different grant programs sponsored by NCER, which include P3, SBIR and CNS programs (for the detailed descriptions of each program, see to Appendix B).

We analyzed each program, P3, SBIR and CNS individually as each has its own goals and grantees. We did not consider NCER's other funded programs such as Fellowships, Technology for

Sustainable Environment (TSE), and non-program specific projects in our analysis because most of these projects were either financially insignificant or required by Congress. Our liaisons also suggested that we not analyze these projects because they do not have the authority to alter the decision of Congress.

To have a holistic view of the distribution of green building research in different EPA grant programs, we counted them and compared them in term of dollars funded and of number of projects. Comparing the two metrics gave us an overview of the allocation of funding for green building research. Table 4-1 shows the amount of funding and the number of projects NCER has supported for green building research in each program since 1995. Not surprisingly, in terms of numbers of projects, P3 is the leader of green building funded projects. This program has granted money to 61 different projects since it has founded in 2003. However, since P3 has always received a small amount of money for phase I projects, often $10,000, and the results are mainly to stimulate public interest and promote social acceptance of green building design. With P3 having significantly more projects it would seem that a large quantity of funding would be present. There have been only two P3 projects pertaining to green building that have received phase II grants.

Table 4-1: Total green building funding since 1995 by NCER grant programs

Program	Funding	Number of Projects
SBIR	$1,872,189	13
P3	$849,049	60
CNS	$2,043,295	8
Fellowships	$738,081	10
Other	$2,160,827	4
Totals	**$7,663,441.00**	**95**

Unlike the P3 program, the CNS program only has a total of 8 projects related to green building and sustainability planning since 2000. Although have much less quantitatively, the CNS provided far more money, more than double the amount of P3 budget. The reason is CNS program's grantees are local organizations and government who seeking funding for large scale sustainable planning. These projects often are very costly due to the scalability of the data and methods. SBIR had 13 related projects. SBIR concentrates mainly on the development of a product or a tool to help sustainable design.

There were also 4 projects that were placed into the "Other" category, as shown in Table 4-1. These projects account for $2.1 million of research funding. However, included in this category are federally mandated project. While these projects focus on relevant topics, we will not provide the same level of depth of analysis for them. Neither NCER nor the EPA can change the research direction or the size of the grants for any future projects. As our goal is to identify the future directions of green building research, we only provide an overview analysis.

To further analyze the fiscal breakdown we graphed what percent of the total funding each grant program encompasses. This breakdown further shows that the P3 program is the smallest in terms of financial awards, making up approximately 11% of the total funding by NCER. The CNS and SBIR programs are found to be similar in size in terms of the number of dollars. Figure 4-1 also shows that the "Other" category is similar in size to both the CNS and SBIR.

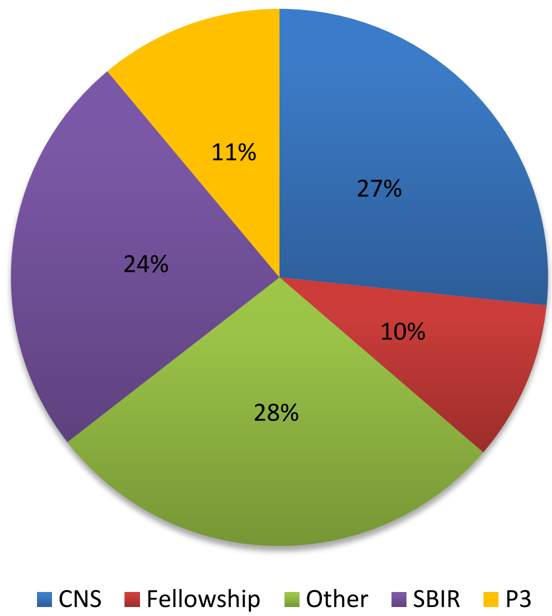


Figure 4-1: NCER's green building funding by different program since 1995 (dollars)

Analyzing the past research exclusively by using financial criteria gives us an incomplete view of the situation because the amount of budget giving for each programs are different. For example, if we only analyzed these data by the amount of dollars represented in Figure 4-1, there would be significant differences in what conclusions we could reach. Therefore, it is not reasonable to only compare the amount of funding among these programs. We made further comparisons by the number of projects that each program had funded as well.

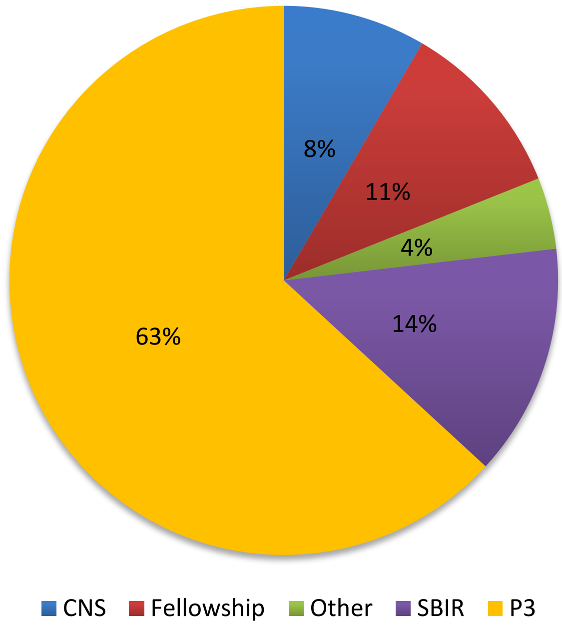


Figure 4-2: NCER's green building funding since 1995 (number of projects)

In Figure 4-2 we graphed the percentage of the total number of projects each grant program has supported. This shows that the P3 program makes up over 60% of the total number of funded projects. The P3 program is able to award so many grants because the award size is significantly smaller than the other grant programs, $10,000 for Phase I. On the other hand, the CNS projects focus on solving environmental issues on a large scale. Therefore, it is often more costly and requires a significant amount of work, resulting in only several projects funded each year.

The "*Other*" and *Fellowship* categories of related to green building research show interesting characteristics. The "*Other*" category has received 28% of NCER's funding related to green building, but only makes up 4% of the number of projects funded. One of the projects in the "*Other*" category received an approximate $900,000 grant. It may seem like the funding size of this project is an outlier for our dataset and that it is overly influencing our data set, but this project's topic is related to green building technology. This project titled "*Infrastructure Systems, Services, and Climate Change: Integrated Impacts and Response Strategies for the Boston Metropolitan Area*" includes important aspects of social acceptance, explaining its inclusion in our list. The *Fellowship* program encompasses only 11% of the projects and 10% of the funding. These grants go towards graduated students typically working on environmental research or sustainability.

When analyzing these data it is important to remember that each of these grant programs typically award grants of a similar size every year. Therefore, it is essential not to draw conclusions on which program has had more success with green building and related research solely by considering these data.

4.1.1 Green Building Research Trends

The past research funded by NCER concerning green building and related technologies began in 1995 with the reorganization of the Office of Research and Development (ORD). To understand funding trends over time our list of 95 projects had to be organized by the year funded and the program that received the funding. Once again we analyzed the data both by the number of projects and the size of the awards.

Before we provide analysis of these research trends, it is important to note how the data were interpreted. Many of the projects funded by NCER are sponsored for 2 to 3 years, particularly in the SBIR and CNS programs. We wanted to know the value of how much yearly funding is awarded by NCER towards green building research. Therefore Figure 4-3, which shows the funding trends of each program over time, was developed by dividing a project's total funding by the number of years the project was carried out. To eliminate confusion for Figure 4-4, which shows the number of projects sponsored per year, each project is counted only in the year it was first funded. For example, if a two year project was awarded $100,000 in the year 2000 our chart would show that the project was done in 2000, but the funding was distributed as $50,000 in both 2000 and 2001.

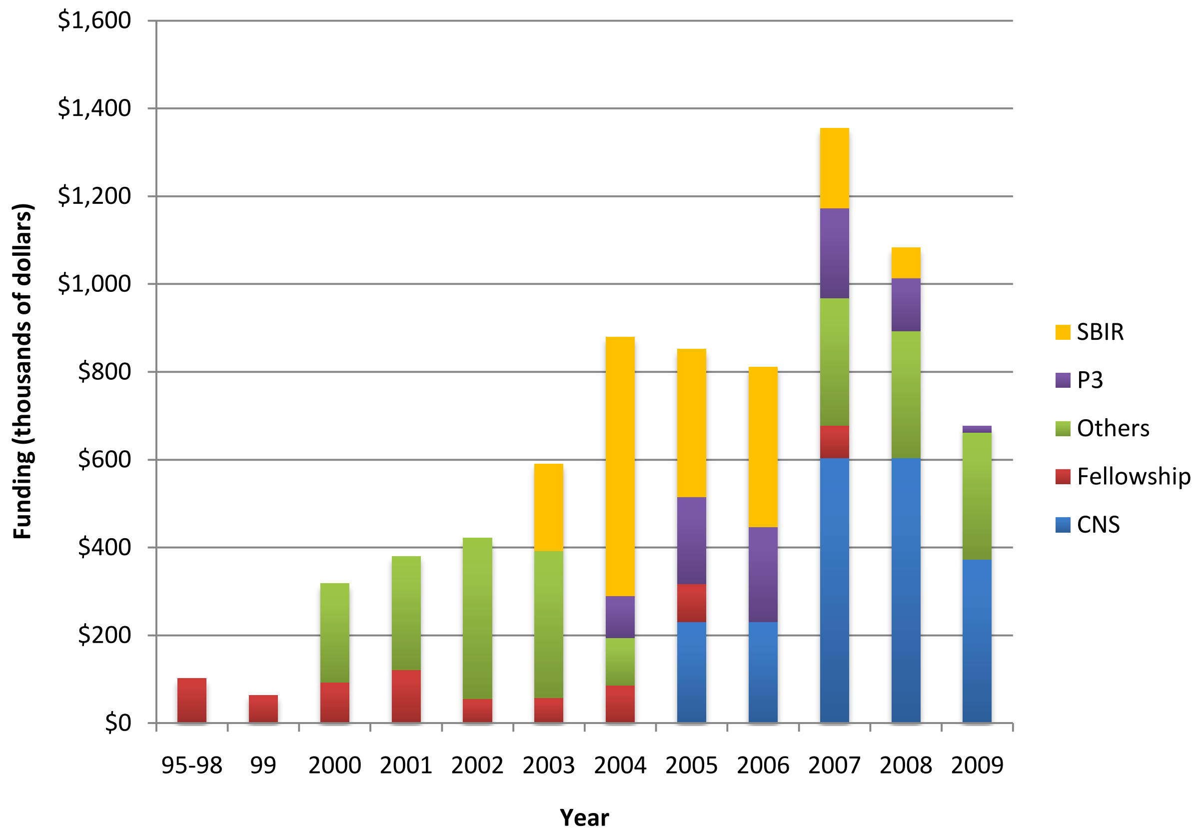


Figure 4-3: NCER's green building funding since 1995 by dollar

As shown by Figure 4-3, the general funding trend for green building research appears to be increasing over time. However, after 2007 there are two consecutive years of decreasing funding. This is attributed to proposals still being considered for funding and projects that have not yet been entered into the database.

The CNS program has funded a large amount of grants since 2005 and peaked in 2007 in terms of dollars (Figure 4-3). The purpose of the CNS program was to become the cornerstone of NCER's shift towards sustainability research. It requires significantly more capital to perform the large-scale regionally focused sustainability projects that CNS targets. The program is a significant progress contributing to green building research. Although all CNS projects have different topics, their approach method of solving the problem in the large scale had partially fixed the gaps of scalability that has been overlooked in the past.

After the year 2004 the SBIR program experiences a decreasing trend in amount of funding. This was a result of the gradual NCER budget cuts since 2004. Since SBIR program represents 2.5% of the total NCER funding, the decreasing funding of SBIR would signal the overall decreasing of NCER fund. The SBIR program currently contains one-half the funding resources it once had. Even with the budget cuts, in 2004 the number of green building SBIR projects doubled that of the previous year. This is because 2004 was the first year that SBIR issued a solicitation for green building research. Since 2004 green building has remained on the yearly SBIR solicitation. In terms of dollars granted, green building research under the SBIR program has decreased after its initial year of specific green building solicitation. This is also true with the number of projects funded since 2004, shown in Figure 4-4. However, considering the small number of SBIR green building projects it is difficult to make a conclusive statement.

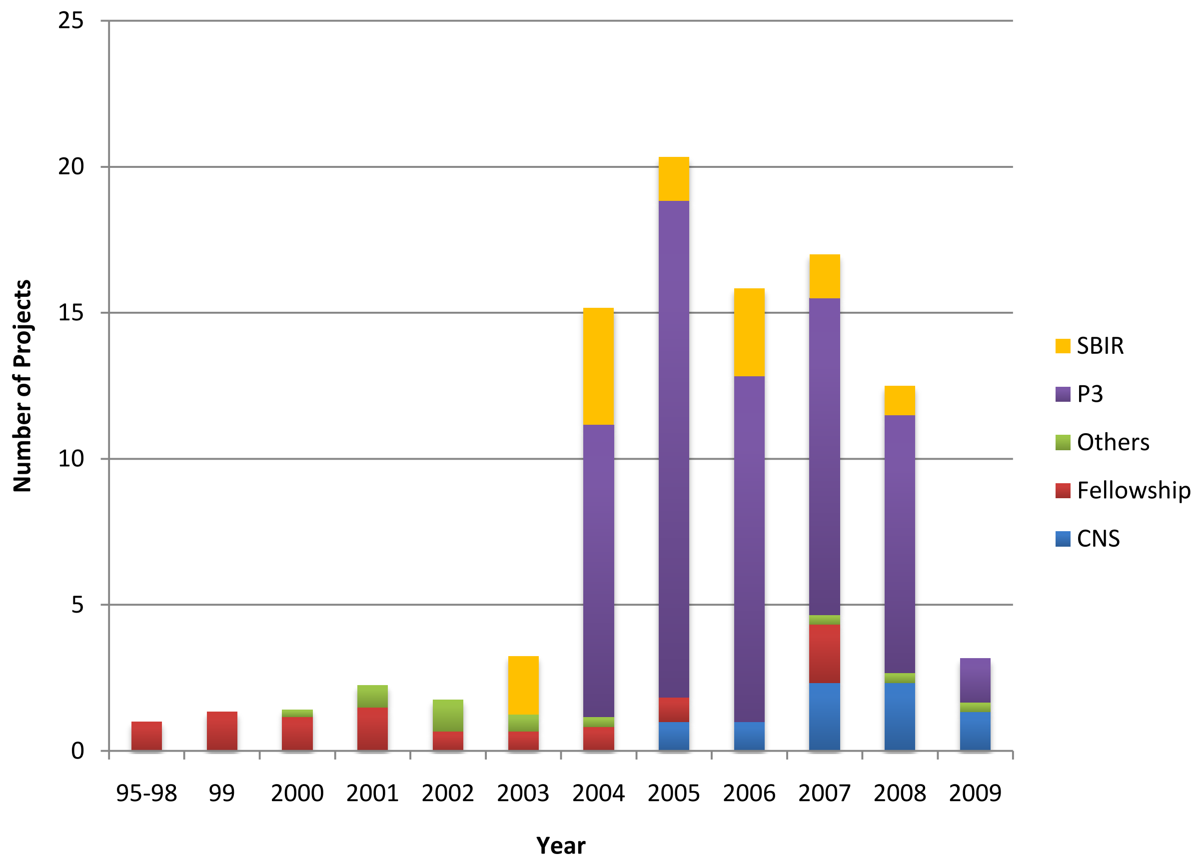


Figure 4-4: NCER's green building funding since 1995 by number of projects

From 2003 to 2004, there is a sudden jump in the number of green building research projects, which is clearly depicted in Figure 4-4. This is largely attributed to the start of the P3 program and the EPA beginning to encourage green building research. Since founding in 2004, the P3 program consistently has had the most relevant projects, but conversely the smallest budget. Between SBIR and CNS, the minimum grant is $70,000 dollars. Therefore, P3 can support a large number of institutions and colleges. This gives P3 the advantage of being able to cover a wider range of topics. Solicitations for the P3 program are far broader in scope than those of CNS or SBIR. This opens the applicant field to far more researchers than the other programs. In addition, the smaller grant size may be more feasible for many projects. On the other hand, the result quality and credibility will not be as accurate as those with larger grant. For all projects, P3 comprises all different aspects of green building including water efficiency, water reuse, stormwater management, and social acceptance. However, the disadvantage of the P3 program is often the scale. Due to the program being an undergraduate competition with comparatively small funding, the depth and extent of research results are limited. We provide a more in-depth analysis of scale can be found in the next section 4.1.2, the categorical analysis.

Although the P3 program contributes a large number of projects related to green building, this number is relatively stagnant at an average of 10 projects and $200,000 per year. Each year, there is one P3 project receiving Phase II award of $75,000, which explains why the amount number $200,000 not corresponding with the average 10 projects. This shows that although there was a shift of interest to green building in 2003 when the P3 program was created, the overall interest remains the same. It is important to note that due to confidentiality we do not know the number of green building project proposals submitted annually to P3, or to any other program at NCER. The possibility exists that the number of green building project proposals is increasing, but they do not receive funding.

It is also important to consider that green building is such a new research area. Therefore, many of the NCER funding programs do not have a significant number of related projects. As we mentioned earlier, green building research only receives less than 2% of total NCER funding. As a result, we have a small data base of projects from which to draw our conclusions. Particularly with the SBIR and CNS programs this could result in interpretations of data that are not actually significant. Therefore, it is important to refrain from making final recommendations off just this analysis alone.

4.1.2 Categorical Analysis

To further pinpoint the past and present areas of research that NCER has funded, we analyzed the 95 projects based on their categories. This allowed us to make specific observations about which areas of research, particularly water infrastructure, had previously been funded. Once again we analyzed this data by both the number of projects devoted to a category and the amount of dollars a category received.

Table 4-2: Detailed categories used to classify project

	Categories	Details
Scale	**Site Specific**	The project is related to the design of a single building
	Commercial	Schools, offices, large apartment complexes, etc.
	Residential	Single houses and small apartment buildings
	Regional	The project is related to large scale planning such as a region or a community.
	General	The project can be implemented everywhere.
Media	**Multimedia**	The project considers 3 or more aspects of green building media.
	Wastewater	The project is related to the treatment or reuse of wastewater generated from construction or operation of a building.
	Reuse	The wastewater is treated and reused.
	Pretreatment	The wastewater is pre-treated before disposal to municipal system.
	Stormwater	The project is related to stormwater management practices or stormwater treatment.
	Green roof	The project is related to designing, improving, or maintaining ecology roof used for stormwater management.
	Watershed	The project is related to urban planning and stormwater management into local reservoirs or ponds in order to treat stormwater from a large area.
	Others	The project is related to other stormwater management practices such as rain barrels, rain gardens, pervious pavements, etc.
	Water efficiency	The project is related to improving the efficiency of water usage while maintaining the effective performance.
	Energy efficiency	The project is related to improving the efficiency of electricity, heating or using alternative energy such as wind and solar energy.
	Material	The project is related to the use of green materials in construction or the reuse of waste material from demolition.
	Indoor Air	The project is related to the improvement of ventilation and indoor air flow within a green building
Approach	**Planning**	The project is related to sustainability planning of a region and a community, not specifically related to green building.
	Technologies	The project is related to developing or improving technical aspects of a green building e.g. stormwater control devices.
	Metrics	The project is related to the development of metrics or methods to monitor performance.
	Implementation	The project is related to the design or implementation of green practices
	Social Acceptance	The project is related to educating consumers on green building practices

As was mentioned briefly in the previous section, our list of categories is based on three dimensions. We designed our categories to allow every project to fit into each of the three dimensions. This allowed us to draw comparisons between the projects. The first dimension is *Scale*. *Scale* is simply a way to determine if a project was focused on a *Specific Building* or a *Region*. It also allowed us to identify if the project dealt with either *Residential* or *Commercial* sectors. We wanted to compare between residential and commercial green building research because the technologies used are significantly different in terms of size, cost, and usability. Another category in this dimension that we created is *General*. If a project is simply a technology that does not have a limitation on size of implementation and can be used in different types of building then it will be placed into this *General* category.

Our second dimension is *Media. Media* refers to the research field of green technology. Being that the focus of our project is on water infrastructure, we created more detailed categories for *Wastewater* and *Stormwater*. For *Stormwater* category, we elected to create common subcategories including *Green roofs*, *Watersheds*, and *Other Stormwater Methods*. The subcategory *Other Stormwater Methods* refers to such devices as rain gardens and rain barrels. Adding to our water infrastructure focus, we also classified projects that fell into non-water related categories. These categories include E*nergy*, *Indoor air*, and *Materials*. We wanted to get a broad understanding of all green building research areas NCER has funded. Since some projects deal with the construction of an entire green building and may consider many, if not all, aspects of green technology, we placed them into the *Multimedia* category.

The final dimension that a project must be placed into is *Approach. Approach* refers to how a project contributes to the advancement of green building. This dimension is split into two subdivisions. The categories *Technologies, Performance metrics,* and *Planning* are grouped together in one subdivision, which means that every project must be placed into one of those three categories. *Technology* projects deal specifically with the development of a green device that is designed for, or could be used in, a green building. *Performance metrics* refers to projects that deal with the development of methods to rate or evaluate buildings. The final category, *Planning*, refers to projects devoted to planning of green communities or finding long term solutions to reduce environmental impacts.

The other subdivision of the *Approach* dimension is used to categorize projects into either *Implementation* or *Social Acceptance*. Projects that fall into the *Implementation* category have the end goal of creating a tangible object, such as a green building or a measuring device. Contrary to *Implementation* projects, *Social Acceptance* projects deal with improving the social acceptance of green building such as projects that increase social awareness of ways to increase water and energy efficiency.

After developing our categories and placing each project into the 3 dimensions we were able to graph the data to have a visual representation of the past research. As expected, *Site Specific* research has received less attention compared with *Regional* and *General* categories, which is displayed in Figure 4-5. The large number of projects in *Regional* is due to the CNS program, which explained the progressive direction of NCER toward large scale planning. This agrees with the EPA's ultimate goal of having the largest and widest effect possible on the environment. This goal coincides with many of the projects dealing with making large scale influences. An example of this is the CNS project "*Mapping Regional Development for Smart Growth Planning to Minimize Degradation of Water Quality and Enhance Green Infrastructure*". This project is just one example of EPA promoting regional green development, which was a primary focus of the CNS program. Further analysis of individual projects and programs will be discussed in more detail in the following sections.

General research, which can be applied to any building, has also received significant attention. This shows that past research of NCER has not focused on the climatic and regional difference between areas in the US. We knew that technology such as green roof changes significantly between areas, especially in the U.S. where there are many different complex weather areas that needs more research to adapt current technologies into these regions.

The *General* and *Regional* categories combined show that many of the previous NCER sponsored projects focus on large scale green building development. Although a large amount of money has been put to sustainability design on a large scale, mostly from CNS programs, the research focused on the sustainable design of public places such as parking lots and streets, there is little research studying the combining impacts of buildings on the water infrastructures and the environment. We know that one building can have significant impacts on water infrastructure. A group of buildings have much bigger impacts which it often harder and more expensive to measure and to control these impacts. This leaves *Site Specific* research needing more focus.

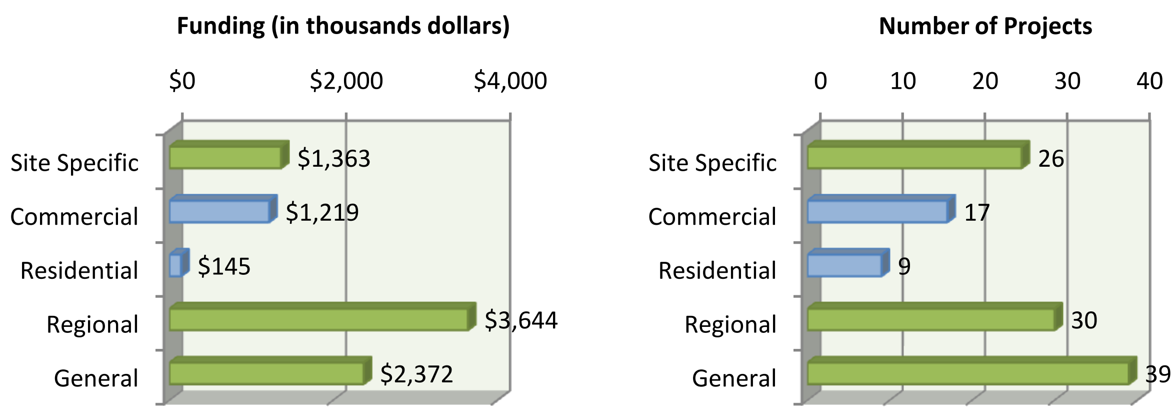


Figure 4-5: NCER's green building funding in scale dimension

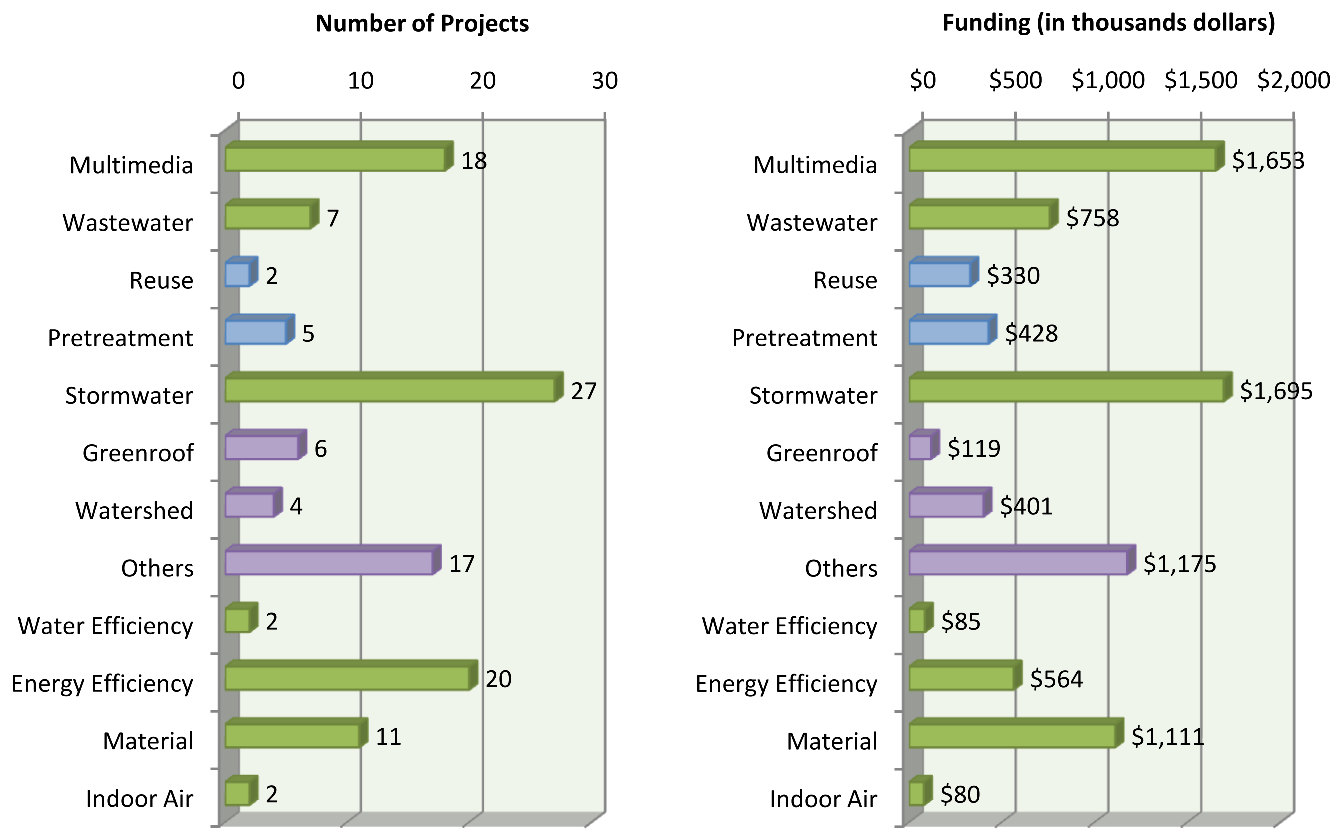


Figure 4-6: NCER green building funding in media dimension

One of the first observations of this data is the limited research devoted to *Wastewater*. There are only 7 projects dealing with wastewater with a total funding of $758,000. This important area of research encompasses both *Reuse*, and *Pretreatment* categories. As shown by Figure 4-6 *Reuse* is the subject of only 2 projects. To emphasize how limited the research in this area has been, it is essential to note that *Reuse* includes both grey and black water. Of this limited research, NCER has focused predominately on grey water, leaving black water with even less attention. The depth of research and technology requirements needed to manage each of these types of water future attention.

Water efficiency is an area that NCER has only given $85,000 towards 2 projects. At first glance, this seems like an alarming statistic, due to expectations of significant funding. However, as will be shown in the next section, water efficiency is an area where the EPA does significant internal research.

The *Stormwater* field has a large number of projects but the depth of much of the research is limited. This disproportion is partially explained by stormwater management not looking as in depth as other areas. Of the projects dealing with green roofs, 5 of the 6 are from the P3 program. Though this will be discussed in further detail in the next section, it is important to note that several principal investigators of green roof projects mentioned that green roof research is incomplete. Specifically, topics needed include growth media, runoff, and plant selection. However, a problem has been identified in living system research including green roof is that the climate factor affects a lot the choice of media, species and methods to maintain the systems. This would require a lot of funding for different areas in the U.S.

Categories other than water make up a significant portion of past NCER research. *Energy efficiency* and *Materials* account for 31 of the 95 green building related projects. These 31 projects unrelated to water show that in the past there was a higher interest in these other areas. Another important category, *Indoor air,* has only 2 projects and 80 thousand dollars worth of funding. This makes it seem as though this topic is ignored but in actuality the EPA does a significant amount of internal research on air quality.

After considering both the *Scale* and *Media* dimensions, we continued to analyze the *Approach* dimension. As mentioned previously, this dimension is split into two subcategories. Since every project must fit into one of *Technology, Performance metrics,* or *Planning* subcategories, it is interesting to note that there is a near even spread of projects between *Technology* and *Performance metrics* in terms of numbers. The funding of these two categories however is very one-sided. There has been $2.33 million spent on *Technology* while over $5 million has been spent on

Performance metrics. Having less past technology funding supports our previous analysis that there are still significant gaps in water research, particularly in water reuse.

The other two subcategories that each project must fall into are *Implementation* and *Social Acceptance*. There have been only 19 past *Social Acceptance* projects; while there have been 76 *Implementation* projects. The funding for these two subcategories is also uneven. There has been over $5.6 million towards implementation, while there has been under $1.8 million towards *Social Acceptance.* While it makes sense that *Social Acceptance* has received less funding than implementation, this category is in need of more research. Developing a green product is useless unless there is a market to utilize that product. As shown throughout our background chapter, there are many simple technologies that are ready for adoption but there is just not enough public awareness and acceptance for implementing them. Examples of such technologies are the simple stormwater management tools such as rain barrels or rain gardens. Further discussion of these gaps can be found in following sections

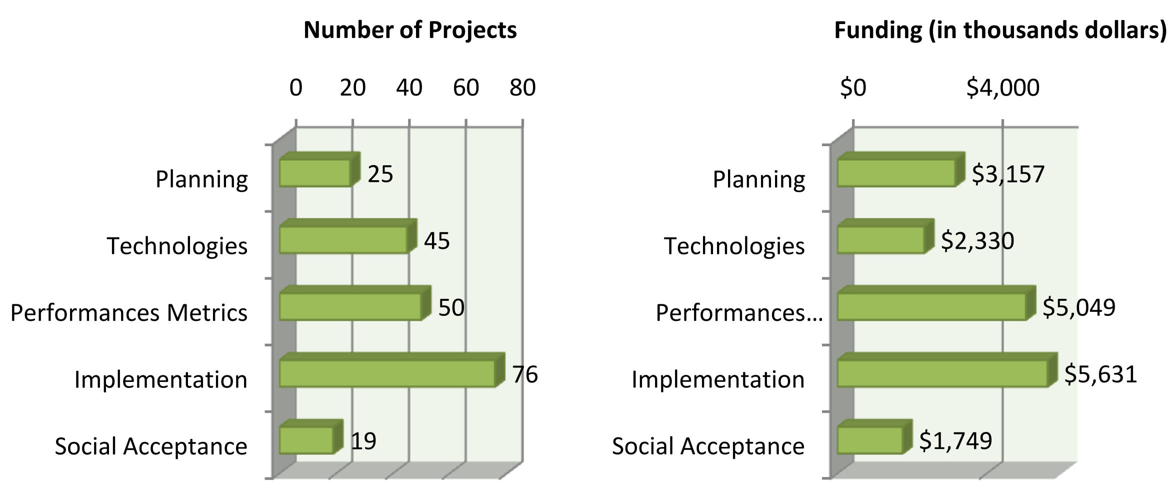


Figure 4-7: NCER green building funding in Approach dimension

Sorting projects by self-made categories inherently has some room for error. Though the four of us ultimately agreed upon the placement of every project, there is always room left for personal interpretation. Another limitation was that since the number of green building projects is relatively small, 95, it is more accurate to say that all areas will need to receive more funding. However, we represent these data in categories to see the distribution and direction of NCER in order to further recommend new priorities to address the green building research gaps better.

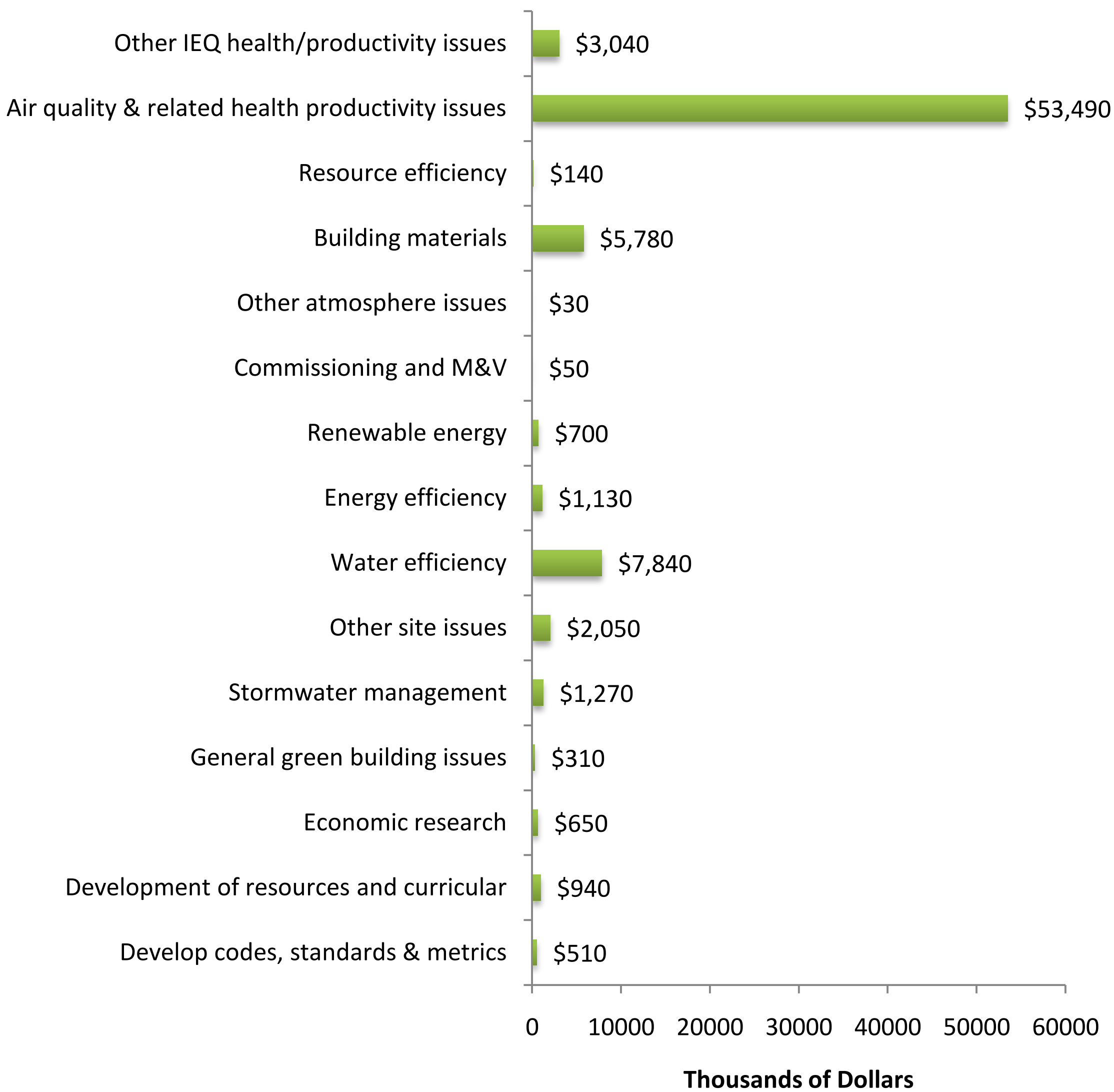


Figure 4-8: EPA Green Building Research Funding by Topic from 2002 to 2006

Compared with the overall EPA's green building research from a study of the USGBC in 2006, the categories of *Water Efficiency* and *Indoor Air* has been focused by other offices in the EPA. It made sense that this was not an agenda in NCER.

4.1.3 Project Investigator Interviews

After having categorized the 95 NCER sponsored projects, we selected approximately 20 that gave us a range of green building technologies to further analyze. We selected projects that dealt with topics such as green roofs, green stormwater materials, and social acceptance. These projects were selected from the 3 main NCER project programs, P3, SBIR, and CNS. However, of the 20 Project Investigators contacted for an interview, only PIs of 10 projects were successfully contacted. This list of 10 projects can be found in Appendix F. Once contacted, we were able to interview with 11 PIs of 10 projects on their opinions of what areas in green building and water infrastructure research require more research.

Table 4-3: Interview Matrix

EPA ID	ABSTRACT	GRANT	PROGRAM	Initiative Community	Residential Lack	Water Reuse	Water Incentives	Water reuse risk	Public Acceptance	Permeable Pavement	Regional Climate	Affordability	Existing Building	Post Occupancy	Regulatory
X3832204	**Multi-Objective Decision Model for Urban Water Use: Planning for a Regional Water Reuse Ordinance**	**$255,000**	**CNS**				x					x			x
R833345	**Mapping Regional Development for Smart Growth Planning to Minimize Degradation of Water Quality and Enhance Green Infrastructure**	**$249,919**	**CNS**			x	x								x
X3832207	**Using Market Forces to Implement Sustainable Stormwater Management (Portland)**	**$288,000**	**CNS**	x					x		x		x	x	
SU832501	**The DELTA Smart House: Cross-Disciplinary Projects within the Design Framework of Sustainable Construction**	**$10,000**	**P3**						x					x	
SU833566	**Place-Based Green Building: Integrating Local Environmental and Planning Analysis into Green Building Guidelines**	**$10,000**	**P3**								x	x			x
SU832505	**EVALUATING ecoMOD: Building Performance Monitoring and Post-Occupancy Evaluation of an Ecological, Modular House**	**$10,000**	**P3**									x	x	x	
SU833940	**Permeable Parking: A Green Approach to Managing Water Runoff at the University of St. Francis**	**$10,000**	**P3**							x		x		x	
SU833189	**Optimizing Green Roof Technologies in the Midwest**	**$10,000**	**P3**								x		x		
SU832477	**High Albedo and Environment-Friendly Concrete for Smart Growth and Sustainable Development**	**$10,000**	**P3**							x					
EPD06054	**An Integrated Ecoroof Energy Analysis Model**	**$69,856**	**SBIR**								x	x		x	
WaterSense					x		x	x	x						x
Office of Wetlands, Oceans, and Watersheds				x	X					x		x			
Office of Drinking Water						x	x	X	x					x	
Green Building WorkGroup				x		x			x		x	x	x	x	

Each of the 11 PIs interviewed was asked the same 13 questions found in our interview protocol (see Appendix E). However, not every one of the base 13 questions were relevant to each project, so in some cases questions were omitted as necessary per interview. We were able to perform a content analysis on the data and created a comparison matrix, as displayed by Table 4-3 above.

Stormwater management is an area that was consistently brought up during our PI interviews due to its relevance not only to water infrastructure but also to some of the PIs' projects. Within stormwater management, interviewees focused on green roofs and green paving materials. We interviewed the PIs of three different green roof projects, where each PI shared their ideas on current research gaps. It was brought to our attention that all of the technical advances made in Germany regarding green roofs can not be applied in the United States. Differences in climate, flora, and soil are too great for German research to be of use in the United States. Another interesting research area is how to adapt green roofs to buildings with pitched roofs. The majority of residential homes feature this roof design; therefore if green roofs were to be considered for this mass market, more research would need to be done to arrive at a suitable green roof design. There are important considerations for a green-pitched roof, such as the potential for more nutrient runoff, and other structural concerns.

Several PIs mentioned that green roofs have other equally beneficial characteristics in addition to reducing stormwater runoff. Theoretically, green roofs significantly reduce the urban heat island effect of a building and reduce the heating and cooling costs of the building. However, there is not enough data to support to these theories. Although, the PIs have noticed these benefits after implementing the green roofs, they believe more research would be necessary before determining if the thermal benefits of green roofs are as significant as currently theorized. The PIs also recommended further research into the life cycle of the green roofs as well as making them more cost effective and easier to implement.

Besides green roofs, we interviewed two project PIs who did research on green materials. One such ongoing project dealt with pervious paving. These porous materials they are researching will allow liquid to flow through them into the ground below, therefore eliminating stormwater runoff. More information is necessary in order to determine how effective the pervious pavements would be in managing stormwater runoff. Other than pervious pavements, the albedo content of pavements was an interest to one of the PIs. The project dealt with increasing the albedo (the reflectivity of a surface) content in concrete and making it more environmentally friendly by adding different levels of fly ash or slag to the concrete mixture. This is necessary due to the heat island effect caused when the pavement absorbs solar energy, which increases the surrounding temperature, decreasing air quality and posing a threat to human health. However, the government has limits on the amount of fly ash/slag contained in concrete mixtures. Although this limit made sense before, the PI was concerned that this limitation is not appropriate. More research into this topic would give the government more information to make better policies.

Two of the PIs interviewed dealt with a building and its performance rather than specific parts of the building like the roof or the surrounding areas like the pavement surfaces. From the interviews, we learned that an important tool missing from the design and implementation of green buildings and related technologies is a software tool that allows designers, architects, engineers, etc to easily find the necessary information that would aid in designing green buildings. The information could include different methods and technologies that others have used successfully, which would increase awareness in the architectural community of different green building technologies and methods.

While green buildings and green technologies are important, two of the PIs were concerned with sustainable development. One of the projects was on mapping regional development. Due to the increase in population, there is a lot of community growth and urban sprawl, some of which is unplanned. The PI of this project raised the question of the hidden costs of development such as in cases where urban sprawling alters natural water flow patterns and can lead to long-term costs for the community.

One of the common complaints issued by the PIs is the lack of data on a green building's performance after construction. Currently, LEED does not require post-occupancy evaluations of the buildings in order to receive certification, which means that there is not much of an incentive for building owners to expend the effort and expenses for the evaluations, In order to convince the public and the government the benefits of green building more data would have to be acquired on the long-term performance. Another issue raised by the PIs is the lack of government guidelines in certain green technology areas such as water reuse. With more data collected from research and after implementation of these technologies, the government would be better equipped to make policies that provide better guidelines on the implementation of the technology. At this time, water reuse is governed in by each state's government,, which makes regulating water reuse across the border a bit of a challenge, especially in certain areas that do not face as much water resource challenges. These areas do not have the incentives to reuse their water or the knowledge of any health risks in recycled water and thus the laws are much more limiting than necessary. However, according to the PIs, were there more information on recycled water, such as the health risks and costs involved, the government would better able to make policies that deal with water reuse on a federal level.

It is important to note that some of the information from the interviews with the PIs may be biased in favor of their particular research projects and areas of expertise. Therefore, the data they have provided, though correct, must be considered with the opinions and data from other sources In order to minimize biases. In retrospect it would have been beneficial if we were able to interview with more PIs. Our initial goal was to interview with 15 projects, but after sending emails to 21 different projects we only received responses from 10 projects. This was done by interviewing EPA employees and looking at other information provided by other organizations such as USGBC.

4.2 External NCER Research

The NCER is only one office within the EPA interested in continuing and focusing their green building research. The EPA is divided into many offices such as the Office of Research and Development (ORD) of which NCER is a part. There are other offices within the EPA, such as the Office of Wetlands, Oceans, and Watersheds (OWOW), Office of Pollution Prevention and Toxics (OPPT), and Office of Water (OW), also working on sustainable green building technologies. Often these offices' goals are not green building directly, but instead a specific technology that is or could be implemented in a green building. For example, OWOW does extensive research on stormwater prevention devices while OW works a lot on wastewater treatment. On a broader scale, there are also other federal government agencies such as National Science Foundation (NSF) that have completed or are currently working on green building related research. Other non-profit organizations such as the U.S. Green Building Council (USGBC) and the American Society of Landscape Architect (ASLA) are also researching green buildings and related technologies. By considering all different organizations, we understood the green building research focus in a broad scale to provide accurate recommendation fitted with the EPA's mission while not overlapping with existed research from others. For easier reference during this chapter, Table 4-4 shows the list of people outside of the NCER that we interviewed. The detailed interview transcript can be found in the Appendix F – EPA Offices Interviews.

Table 4-4: Interviewees outside of the NCER

Name	Office
Jamal Kadri	OWOW
Abby Hall	OWOW
Audrey Levine	ORD – Drinking Water Research Program
Alison Kinn	OPPT
Ken Sandler	U.S. EPA Green Building Workgroup, USGBC
Stephanie Tanner	U.S. EPA Office of Water, WaterSense
Elizabeth Guthrie	ASLA
Keith Swann	ASLA

We also compared the amount of funding of two categories in *Media* dimension with the funding data found in "*Green Building Research Funding: An Assessment of Current Activity in the United States*" produced by the USGBC (2006). The funding data in the USGBC research report are from 2002 to 2006. Therefore, we calculated the amount of NCER's funding in the equivalent time period for the data to be comparable with USGBC's information. One of the factors that affect the validity of this comparison is that the criteria the USGBC used for each category and the criteria that we used (described in Chapter 3) may be different. The categories we chose to compare are *Water Efficiency* and *Stormwater Management* because they are the only categories the USGBC used that are related to our project's focus. These categories are clear enough so that we can safely assume the criteria of the USGBC and ours are more likely to be similar. We only chose to compare with research from the NSF because they are the only agency that has a similar research topic and focus as the EPA. Moreover, we also compare with the EPA internal research to reflect the different in focus.

4.2.1 Stormwater

Implementation of green building technology, specifically stormwater is lacking attention. Ms. Abby Hall and Mr. Jamal Kadri from OWOW stressed that although the technologies for better stormwater management exist, there are many barriers to implementation. The biggest barrier is public awareness. Currently, implementation of stormwater practices such as green roof requires professionals for installation, which usually cost additional expense over using traditional roofing materials. Were the technology easier and cheaper to implement, it would be more readily available to the general public, thus more people would be willing to implement it. Ms. Hall and Mr. Kadri also supported the position that there is a lack of quantitative data proving the effectiveness of green roofs and other stormwater practices in urban areas. There are also very few incentives for implementation, especially for residential owners. They agreed with our other sources that there are many effective and simple stormwater practices such rain barrel and rain garden that could be implemented easily.

As discussed in the previous section, we found that NCER has limited funding related to stormwater management. We wanted to check to see if this was consistent with other agencies doing green building research. According to the USGBC study, between 2002 and 2006, the NSF has funded slightly over $400,000 worth of stormwater management research. This is approximately one third of what NCER has sponsored for the same duration (See Figure 4-9). This showed that stormwater management has only been researched mostly by the EPA and NCER. This is the area that NCER should continue focusing in the future.

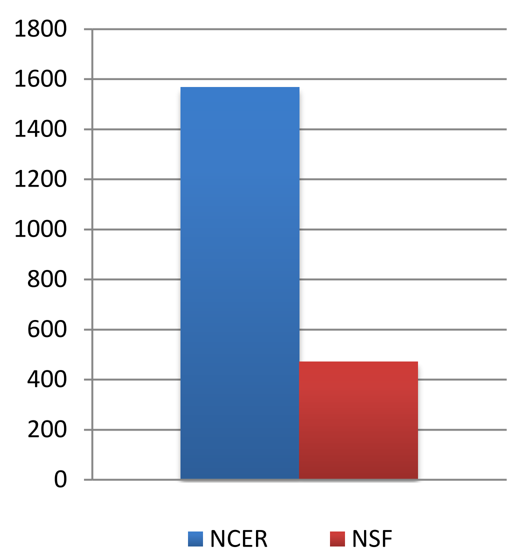


Figure 4-9: Stormwater Funding among NCER and NSF from 2002 to 2006

Although the EPA and NCER has been doing many research on stormwater management, there is still research gaps in many areas where funding are simply insufficient. One of the most important areas is green roofs. Mr. Kadri and Ms. Abby Hall supported a lot of benefits of living ecological system that requires little maintenance while effective in reducing runoff. They brought up some areas of green roof that needs more research including regional climate adaptability and growing media.

Mr. Kadri and Ms. Hall also mentioned about project DX, a project spin off from the Portland project that implemented many stormwater practices on a large scale. The government of the city of Portland, which received funding from the NCER through project DX, has promoted many low impact development practices for stormwater management such as vegetated swales, porous pavers, and infiltration planters. This helps reducing a significant amount of stormwater runoff effectively and increases the public awareness of what people can do on their own properties.

4.2.2 Water

Water research has been fragmented into different areas instead of being viewed as a whole connected cycle. Dr. Audrey Levine, the director of the U.S. EPA National Drinking Water Research Program, had shared her thoughts with us regarding this issue. From this interview, we gathered information about current problems associated with drinking water, water recycling and water infrastructure. One of the key things emphasized by Dr. Levine was that water should not be thought of as separated into different categories such as recycled, grey and black water and stormwater, but we should have an integrated view and look at the whole system and how it is transported and used. Researchers should consider the energy used for water and wastewater transportation into cost and benefit analysis in order to more accurately address the problem. One of the areas that need more attention, according to Dr. Levine, is reusing water on site instead of transporting it. Reusing water increases the proximity of water to the building, which would reduce significant required energy and make the process of delivering drinking water and transporting wastewater much more efficiently. Also, using high quality water for potable uses and lower quality water for other uses would save water and energy, especially in regions where water resources are scarce.

As was shown in our analysis of previous NCER research, an area that has received limited funding is water efficiency. NCER has given less than $100,000 towards water efficiency research, while the EPA as a whole has contributed nearly $8 million between 2002 and 2006 (See Figure 4-10). The NSF has contributed even less to water efficiency research, only $50,000 in the same time period. In this area, water efficiency, the EPA has done all its technological research at its own regional laboratories and through programs including the WaterSense. However, according to Ms. Stephanie Tanner from the WaterSense program, there is little research on the implementation of technologies and how to increase people's awareness of using water more efficiently. This is an area which the NCER can support in the future.

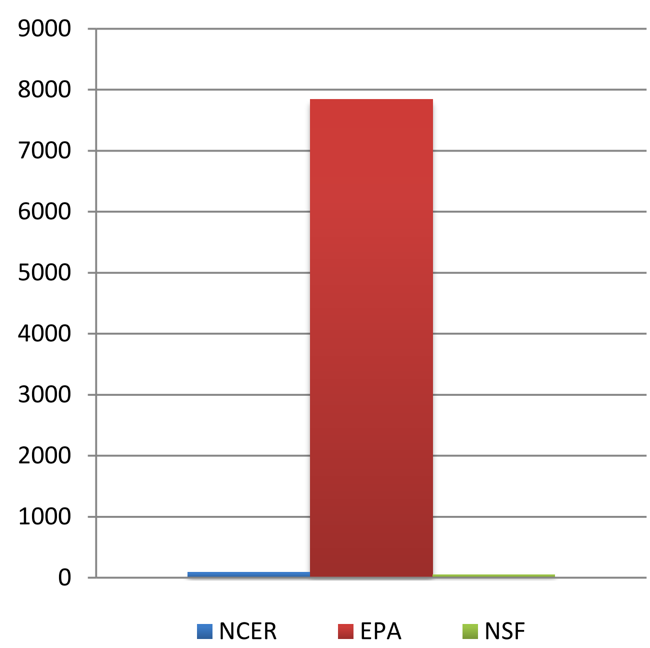


Figure 4-10: Water Efficiency Funding among NCER, EPA, and NSF from 2002 to 2006 (Thousands of Dollars)

4.2.3 LEED's Gaps and Post Occupancy Monitoring

Considering the diverse areas of expertise from all these interviews there were several common themes. Each of the interviewees mentioned a need for ease of implementation of green technologies and more incentives and education for the public on these technologies. They also stressed the need for more data on post-occupancy performance of the green buildings.

We interviewed Ms. Alison Kinn from OPPT and Mr. Ken Sandler from the U.S. EPA Green Building Workgroup. We learned that LEED is currently certifying buildings without evaluating the buildings' performance after people start using them. In order to make green buildings more effective, they believe an evaluation of the entire life cycle of a building is necessary. This will help determine if the building is working as expected and, if the people using it are using it effectively. This will also determine if the material used is efficient overall based on its lifespan as well as its effectiveness during use. Better metrics are also needed to make measuring the effectiveness of green buildings easier. Agreeing with OWOW staves, Ms. Kinn and Mr. Sandler also believe that green technologies would be more frequently adopted if the technologies were easier to use and readily available to the public, especially homeowners.

We interviewed Ms. Stephanie Tanner from EPA's WaterSense program. Ms. Tanner is also a member of the water committee of LEED. She has been working with LEED to better incorporate water efficiency into their rating system. One of the most significant ideas mentioned was that the LEED system has very few points based on water efficiency, currently only 2 points. There is considerable focus on energy efficiency and the utilization of alternative energy, but water efficiency is often overlooked.

Since there is so much emphasis on reducing buildings' energy consumption, one of the most common technologies used in today's green buildings is water towers. Typically found sitting atop the building these towers use water to transfer energy to cool the air rather than using energy intensive HVAC systems. These cooling towers have not been rated by LEED yet in terms of the amount of water they use and also the quality of water they discharge. The WaterSense program has an interest in researching these devices to reduce their water consumption. Ms. Tanner said that a future area that the WaterSense program is looking into is the impact of being water efficient on the larger water infrastructure. There are no data available for knowing the impacts of using less water on the existing water infrastructure. She emphasized that using less water would ultimately reduce the needs for building more water and wastewater treatment plants as well as the needs for larger water distribution systems.

Compared with the EPA and other agencies, non-profit environmental organizations such as USGBC and local governments only have a limited amount of money for green building research, especially when there is no green building strategy. In response to their published research "*Green Building Research Funding: An Assessment of Current Activity in the United States*" showing a lack of research funding on green building, the USGBC committed $2 million to act on the areas in need mentioned in the paper and to leverage other trends as well as encourage other organizations to increase their funding on green building. Of the projects that they funded, most of them focus at implementation and how to promote green building practices. Local governments and organizations are the closest form of management for the implementation of new technologies with minimum bureaucratic delay. However, they still receive very little funding to support green building practices.

4.3 Wide Scale Sustainability Implementation

Implementing green building on a large scale is suspected to have significant benefits to the environment and larger infrastructures, specifically water and wastewater. With contributions from the CNS program, Portland Oregon implemented a vast stormwater management system throughout the city to reduce stormwater runoff. Green building technologies, such as water efficiency and water reuse can ease the burden on the increasing demand for water. Water reuse has been implemented on a large scale in a growing number of areas where natural water resources are rapidly depleting. The scarcity of resources forces the cities in these areas to become the early adopters of the sustainable technology and planning in large scale. Orange County is an example of an area with a shortage of water that led to the development of intensive water reuse program.

4.3.1 Sustainability in Portland

Starting 10 years ago, the city of Portland, Oregon, made a move toward sustainable development. The city decided to become initiative to implement environmentally friendly practices to their surrounding, especially practices to reduce or eliminate stormwater runoff. Their movement is sparked by the rising interest in weaving "green into the grey fabric." This movement is supported by NCER through the CNS program in 2003 because of the sustainability goal of the project.

The city acts as an influential factor that affects the attitude of the people who are living in it. When there are many green design constructed and managed in the city, the people will not only witness the benefit these practices bring to the environment but also gradually start to see these practices as common and not something extraordinary. It helps to increase public awareness and indirectly urge people to become greener. There will be a tipping point where the number of green-minded people becomes great enough to allow going green to become the new fashion.

Before, the problem existed is that people who want to go green do not know where to get the information. Realizing the problem, the city begins to provide manual and guide about low impact development practices that a person can easily implement at the house to reduce stormwater runoff. These practices are often not complicated and not too costly while still providing effective performance.

The method that the city offers to people may not be the most effective method but it can have a large impact when achieving at the scalability of a city. A LEED Platinum certified building can achieve 0% stormwater runoff with different stormwater management methods. While this achievement is enormous to one building, it will be negligible when other buildings still have 100% stormwater runoff. If most buildings just implement a small rain garden, the overall stormwater runoff reduction will be significant. And that is something that can be achieved only with the initiative of the city government.

Another problem of implementing green practices is public incentive. Green practices are often more costly to implement while its benefits are not directly seen by the consumers. Therefore, consumers are reluctant to implement technologies that only benefit the environment. For example, stormwater management practices such as green roof and rain gardens help reduce runoff that can cause erosion and pollution. While those impacts are direct to the environment, people fail to realize that those impacts will eventually affect their health and their water usage … Local cities are at the closest proximity to people that can educate them the importance of their action that can have a large impacts on the environment and themselves. The cities can also provide different types of incentives, from giving awards to reducing taxes.

After this project, the city started another project, called Project DX, to become an initiative example of sustainable design and share their experience with other cities. Project DX is the first step to provide tools and knowledge about stormwater management practices. The city implemented a lot of rain gardens, basins, planters, etc. in the city to reduce the stormwater runoff. The success of this project is largely based on the outreach towards the public. Portland has been able to convince the public the benefit of reducing runoff. As mentioned in the previous section, we interviewed with the Mr. Tom Puttman, the Principle Investigator of Project DX.

As Mr. Puttman told us about Project DX, a large scale data collection is an ongoing process and will take a lot of time and work. Trends so far has showed that green technologies do indeed reduce the consumption and impacts on the larger infrastructure, but to what extent is unknown.

4.3.2 Orange County's Water Management

California has the one of most intensive water reuse programs in the US. There are several factors which have led to the rapid movement of developing sustainable water infrastructure in California. We have learned that several of the arid regions of California are simply running out of water. Their demand for potable water can no longer be fulfilled strictly from natural sources.

As several EPA offices have mentioned to us about California, Orange County has made a move toward wastewater reuse. Their treatment plant is one of a few in the country that can treat wastewater to a quality that can be discharged back into the soil where it becomes groundwater. Once the water is returned as groundwater it is ready for potable use. This method of discharging what was once wastewater has negative implications on public opinion. During the initial stages of developing the system the term "toilet to tap" was a common description of the process. However, as Dr. Levine, the national director of Drinking Water Research program, repeatedly stressed, the full water cycle must be considered. A better term for this cycle could be "indirect potable use". Ultimately it is these small details, including titling, that will dictate when there will be sufficient public support.

The impacts of treating wastewater for potable use reflect directly toward preventing the depletion of the natural sources. As shown in Figure 4-11, the blue markers represent all existing wastewater treatment plants that discharge into the groundwater. Markers in green are planned sites for future treatment facilities. As shown by the figure, the highest concentration of such facilities is the Southwest region of the United States where water supplies are dwindling. The plant in Orange County, California, which went live in early 2008, is planning to treat 15 million gallons of wastewater per day. Each gallon of water added back to the groundwater is one less gallon needed.

Figure 4-11: The distribution of wastewater reuse treatment plants in the U.S. (PBS, 2008)

An interesting point Dr. Levine mentioned was how many people do not realize that they could have unintentionally used recycled wastewater. An example of this is the Mississippi River. Along the thousands of miles of river, everything from industrial use to local municipalities gets their water from this source. Factories could have potentially discharged polluted water, which might not be treated properly, back into the river. Moreover, the local water treatment plants take water from the river and treat them to potable water for distribution. The predominant use in a local community is the potable water from these treatment plants. After used, the wastewater goes through the traditional treatment methods before being discharged back into the river. This means that anyone south of this location using the Mississippi River as a water source will be taking in water that was once discharged from a treatment plant or a factory. This is called unintentionally indirect water reuse. By the time the water reaches the Mississippi Delta near New Orleans the water could have gone through any number of uses and treatments.

Identical to what Dr. Levine was speaking of with the Mississippi is the Colorado River. Bruce Reznik, who is the executive director of an environmental group known as the San Diego CoastKeeper, says that "We need to get over the notion that we're already -- you know, we're drinking some kind of pure water and toilet-to-tap is something that's unsafe." These types of social influence are necessary for public acceptance of wastewater reuse.

4.3.3 Implementing Into Other Cities

The next logical step for green building and the move toward sustainability is the implementation of green building technologies in other cities across the United States.

While many of the ideas mentioned in section 4.3 are the future of sustainable living, many of these technologies are early in their testing phases. One of the biggest difficulties for wide scale implementation remains social acceptance. Often the technology is accused of being unproven outside the laboratory.

4.4 Budget and Regulations Analysis

To develop suitable recommendations, we had to carefully consider EPA's and NCER'S budget and agency regulations. For example, strict regulation of drinking water has been a big hindrance to implementing water reuse practices and small amounts of money have limited the number of projects the EPA can fund. These regulations and budgets as well as the EPA's and NCER's missions govern the research that NCER decides to fund.

4.4.1 Budget

According to an interview with Dr. William Sanders and Dr. Diana Bauer, NCER employees, the EPA does not have a designated budget for green building related research. Therefore, past research on green building was funded only when a project's objectives fit into NCER's strategic goals. According to the USGBC (2006), the amount of funding for green building research between 2002 and 2005 accounted for 3.16% of the total EPA funding.

EPA's budget has seen consecutive yearly decreases over the past few years. In 2006 it was approximately $7.6 billion and in 2008 it had decreased to $7.1 billion, a 6.6% decrease. NCER has also seen a decline in its budget. From 1999 to 2008, NCER's extramural research funding decreased by nearly half, from about $110 million to approximately $65 million, as shown in Figure 4-12Figure 2-12. With the current issues of global climate change, dwindling water resources, greenhouse gas emissions, among others, a budget decrease compromises NCER's ability to fund the necessary research. As a new area of study, without a research strategy mapped out, the potential benefits of green building is suffering from this budget cut. As previously discussed green building has received less than 2% of the total NCER funding, which is not sufficient if the desired result of green building is to have large scale impacts on the environment.

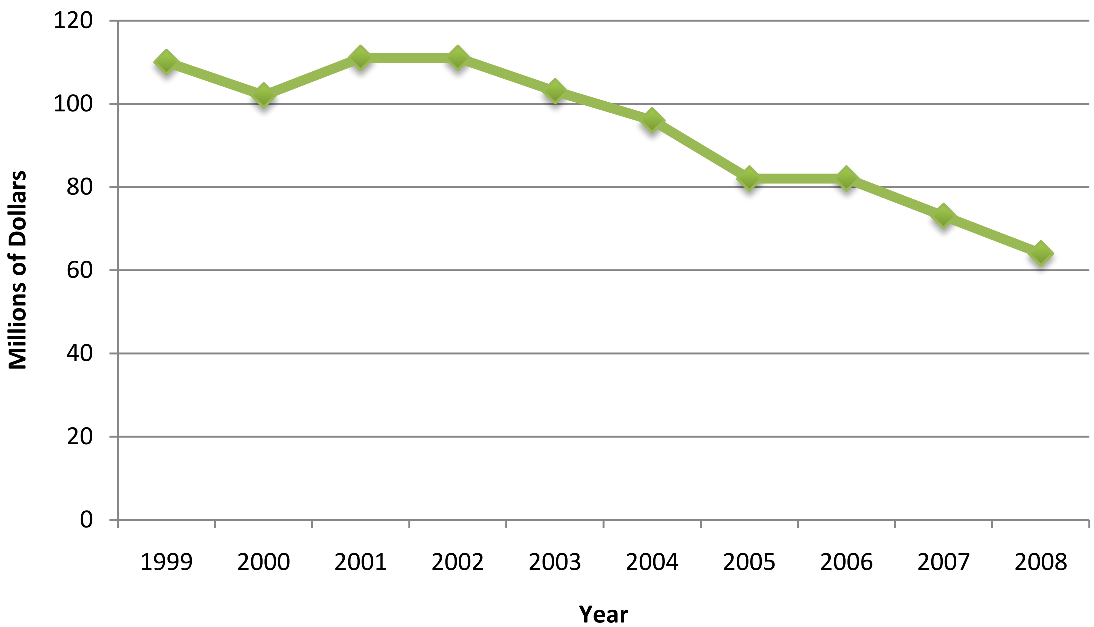


Figure 4-12: NCER Extramural Budget since 1999

4.4.2 Regulations

According to Dr. Audrey Levine, the lack of regulations and policies on water reuse makes it more difficult to push forward research initiatives on recycling and reusing water. The EPA has to first and foremost deal with developing federal regulations. Since there are currently no federal regulations on water reuse, it is difficult to initiate support and explain the need for this type of research. Currently all states have their own regulations on water reuse. However, the level of quality demanded varies from state to state; some state's regulations may be unnecessarily rigid simply due to the lack of knowledge regarding the dangers and risks of reusing water. For example, the Safe Drinking Water Act does not regulate the pharmaceutical contents in recycled water; many states are worried about the human health risks from these chemicals in recycled water, causing them to set stricter policies on water reuse. With more research, the risks involved in reusing water could be discovered, which would help each state set the best policies and also help the federal government set appropriate regulations that would help with recycled water policies.

Table 4-5: Number of States with Regulations or Guidelines for each type of reuse application

Type of Reuse	Number of States
Unrestricted Urban	28
Irrigation	28
Toilet Flushing	10
Fire Protection	9
Construction	9
Landscape Impoudment	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 (Non-potable Aquifer)	5
Indirect Potable Use	5

4.4.3 Regulations

In terms of regulations that aid the EPA and its offices in determining the best research topics, the Clean Water Act Section 104 allows NCER to make grants to institutions and colleges for research regarding the causes, effects, extent, prevention, reduction and elimination of water pollution (refer to Appendix G for more detail). Any research related to green building's impacts on water infrastructure systems such as water reuse and stormwater management can be allowed by the Clean Water Act. For example, under this act, NCER is allowed to fund research on water reuse which will help reduce the amount of wastewater discharged into the environment and stormwater management research which will help reduce the amount of polluted water runoff discharged into water sources.

The Safe Drinking Water Act Section 1442 (Appendix E) also authorizes the EPA to make grants for research on water quality especially in matters of causes, diagnosis, treatment, control, prevention of physical and mental diseases, and other impairments of man resulting directly or indirectly to water quality. Under this Act, NCER can fund various research initiatives on the health risks involved in using recycled water for potable uses. Research into the various pharmaceuticals in recycled water could also be authorized under this act.

5 Conclusions and Recommendations

Water reuse, storm water management practices and water infrastructure are the key research gaps identified through our project. Furthermore, in order to aid implementation of green practices there are significant gaps within social acceptance research. After garnering and analyzing our data from NCER's archive, interviews with project investigators, and employees of EPA and USGBC, we developed two sets of recommendations for NCER.

The first set of recommendations focuses on researching the gaps we have identified through the completion of our objectives. Water reuse, stormwater management practices and water infrastructure were identified as future focus areas for NCER. These areas include water reuse, both regional and onsite, water infrastructure, storm water management and the residential market.

The second set of recommendations concern future focus areas for specific programs within NCER. The P3 program is best suited for localized data collection, such as gathering green roof climatic data. The SBIR program should focus on water reuse technology, which would ultimately result in affordable products for consumers. Finally, the discontinued CNS program needs to be replaced with another sustainable oriented program to continue implementing sustainable design on a large scale. These recommendations will influence NCER's future solicitations to better address areas in need for green building research. They may also prove helpful in the formation of a green building research strategy across the EPA.

Ultimately green building is an integration of many environmental technologies. While we did consider all facets of green building research, our focus was on water infrastructure. We put our primary concentration on technologies dealing with the management of stormwater and wastewater and their resulting impacts on water infrastructure systems. Improving green building technology and implementation would minimize buildings impacts on both the environment and external infrastructures. With the limited budget available to NCER, our project sought to provide research priorities to better focus on aspects of green building that have been previously overlooked. Through our project, we hope these gaps will be better addressed through future NCER solicitations.

5.1 Recommendations for areas of research

We identified water reuse, water infrastructure, storm water management and residential market as areas in need of future research. Also essential for achieving sustainability is social acceptance research. Our analysis of past and present green building research across the EPA has led us to develop a list of future focus areas for green building development, specifically in water and wastewater infrastructure. Due to aging water infrastructure systems, dwindling water resources, and increasing residential construction, these four key areas will need to be address in the move toward sustainability.

5.1.1 Water reuse

One of the most prominent areas of green building that lacks sufficient funding is water reuse. From our analysis, we showed that NCER has funded only $99,000 since 1995, a completely insufficient amount toward this essential research area. Water reuse also has the potential for reducing inefficient non-potable uses, which currently use potable water for tasks such as landscaping and flushing toilet. Water reuse does not only has the potential to significantly reduce the amount of fresh water needed, but also indirectly reduce the energy used for water transportation in and out of the buildings. It also relieves the stress of building more water infrastructure system to meet the increasing demand for potable water.

Water reuse has been overlooked in the past primarily from insufficient knowledge of potential health risks and the high cost of on-site treatment. There has also been essentially no guidance from the federal government regarding the quality of water reuse and the water purification process. This discouraged many cities and states from implementing water reuse program.

1. **Onsite treatment**: More emphasis should be put on developing technologies that could reduce the cost of onsite wastewater treatment. Onsite treatment increases water efficiency and reduce the energy used to transport water. NCER should create a short-term goal of improving non-potable treatment methods, as grey water account for a large percentage of water use. A long-term goal can be to develop these technologies to a level that they can be implemented cheaply and efficiently into existing buildings.
2. **Water reuse risk:** The lack of information on potential human risks from consuming reused water is a big drawback to the implementation process. Future research should focus on identifying any negative consequences associated with water reuse, such as the buildup of pharmaceuticals. Furthermore, research should develop treatment processes to effectively remove these potential risks. Human health is the most important factor when considering implementation of a water reuse program.
3. **Water incentives:** Another problem is the lack of incentives encouraging people to efficiently use their water, which is currently undervalued. An abundance of water in many parts of the US led to inexpensive water bills and creates the impression that water has little value. This also reflected by the low number of points offered for water efficiency in the LEED rating system. Sociological and psychological studies need to be conducted to determine the best method to persuade people to reuse water and become water efficient. Studies could be about the reaction of people to different regulatory methods including taxes and costs associated with water use.
4. **Public acceptance:** Social studies should also aid in determining the most effective methods for changing public perceptions of water reuse. People could be educated about

the feasibility and dangers of water reuse for potable and non-potable purposes. Consumers must understand that there is technology capable of treating wastewater to meet the potable water standards. Future research should study states like California where intensive water reuse has been implemented and how to gradually change the public connotation to accepting water reuse.

5.1.2 Water infrastructure

There is lack of information regarding the impacts of buildings on the larger water infrastructure. City planners and regulators need quantitative data to plan water infrastructure systems that better fit the needs. Water and wastewater treatment plants, water distribution systems, and the piping system all are affected by green buildings impacts. With the aging water infrastructure in the U.S replacements or upgrades will be necessary in the near future. Therefore, it is important to understand these issues to minimize the cost of building more infrastructure systems.

1. **Quantitative data:** Future research should look at collecting quantitative data about impact of buildings on water infrastructure, which could potentially reduce the needs of building more plants as well as relieve the stress on water infrastructure systems by lower total flow.
2. **Water Cooling Tower:** These devices are a specific component to many green buildings that has been overlooked. Typically a large amount of water is used as a heat transfer medium and then discharged as wastewater. This is very inefficient because this used water typically has negligible contamination and could be treated and reused at a minimum cost.
3. **Post Occupancy Monitoring:** Monitoring systems put in place after a building is occupied are essential for maintaining building efficiency. Ensuring a green building is achieving the expected performance after construction is essential if the building is to be different from traditional technologies. However, it is not guaranteed that the building performance can be

maintained after a period of occupancy. Therefore, real-time monitoring is necessary to maintain the efficiency of the building. Computer system can be implemented to monitor and inform consumers about the resource usage at building. It is also important to note that the LEED rating system also has not yet addressed this problem.

5.1.3 Stormwater

Buildings, especially those in urban areas, can significantly reduce the amount of water runoff by implementing proper stormwater management practices. While traditional engineering methods are more reliable, the ever increasing population is resulting in increased impervious surfaces. This requires constructing and managing a larger and more complex piping system at higher operational costs. Ecological systems are a potential solution to solving these stormwater runoff challenges that require further research.

1. **Pervious pavement:** Pervious pavements are important because they not only can reduce the stormwater runoff by releasing the water on site but also help replenishing groundwater resources. Previous NCER research is limited in both scope and depth on this topic. Research into sustainable permeable materials needs more focus.
2. **Affordability:** Stormwater technologies and practices exist, however more emphasis needs to be placed on their costs and marketing. A streamlined process for implementation would be helpful, and research into easily producible technologies would prove useful.
3. **Green roofs on existing buildings:** While it is simpler to implement green roofs on new buildings because the construction is designed to withstand the weight of a living roof, existing buildings may also be able to install green roofs. Future research should improve green roof technologies for ease of implementation on existing buildings.
4. **Climatic Regions:** Future research should include climate into considerations. The various climatic zones act as hindrances for the US to adopt and implement green roofs and other living systems. Research done on a particular area cannot be applied to other areas in other

parts of the country. Future research should focus on methods that can be readily adopted and adjusted for the various climates. Research could also be done on a regional and climate specific basis.

5. **Quality of runoff:** There is little research on the quality of the runoff from different sources. Runoff from parking lots can contain heavy metals, hydrocarbons, and other vehicle related compounds, while runoff from residential areas can contain pesticides and fertilizers. Studying these contaminations can help treating runoff more effectively as well as provide information for future research.

5.1.4 Residential Market

Research should be performed on the simplification of technologies and practices to aid the residential market to accept green building practices. There are approximately 120 million residential units in the United States (US Census Bureau, 2001). As mentioned previously, LEED has a goal of having 1 million homes LEED certified by 2010. This amounts to less than one percent of the current residential market. Having a greater impact on the residential market would be of tremendous environmental value. Traditionally it has been easier to market green building practices and technologies to the commercial and industrial sectors. There also tends to be fewer incentives for residential home owners to implement green technologies. Currently the majority of the market for green building in the residential sector is limited to individuals with the knowledge, money, and desire to be environmentally friendly.

5.2 Recommendations for NCER's programs

Since each program in NCER is different in strategy and budget. To better reflected green building research gaps, each grant program should have different focus considering its nature to provide suitable solicitations encouraging researchers to apply for these grants. The provided recommendations will encourage the direction of future solicitations.

5.2.1 Small Business Innovative Research Program

The focus of the SBIR program is to provide grants for environmental product development. SBIR's grantees are typically entrepreneurs and small business firms. Therefore, projects ultimate goal is often a product that could be commercialized, resulting in profits for the developer. These projects should target products which can be implemented to multiple types of buildings and regions.

The SBIR program should focus on water reuse technologies. This is one of the biggest areas of focus overlooked by NCER. The program could focus on creating affordable on-site water treatment products. An ideal end product would produce different levels of quality treatment for each type of non-potable reuse purpose. For example, there is no need for water of potable quality to be used when flushing a toilet. Grey water reuse requires comparatively elementary treatment processing when compared with that of black water, therefore we recommend as a foremost reuse priority to identify the best methods to treat grey water. Future development should also look at how to monitor water use in real-time for data collection purposes. Past P3 projects have shown that if people are aware of their instantaneous resource use they are more likely to reduce their usage.

Stormwater management is an area where the SBIR program could also show its potential. Future research should focus on measuring the runoff rate and treating the contaminants. Another area to study is different types of soil, plants, and landscape technologies that have lower costs and higher performance. The products should also consider aesthetic design criteria to make them more marketable, as social acceptance is one of the major hindrances to mass implementation.

5.2.2 People, Planet, and Prosperity Program

We believe NCER could better utilize research results from the P3 program. Although P3 has a comparatively small budget, it has the advantage of having a diversity of grantees with various professional backgrounds in different geographic areas. Past recipients in the P3 program have shown they can cover a wide range of topics. The broader solicitations bring the interests of individuals rather than furthering the EPA's own goals. These projects aim at students and universities that are in an easier position to perform sociological studies compared with SBIR. These projects should continue to look at different and effective ways to integrate all aspects of green building together. Quantitative data collection is a very important aspect of green building that the P3 program has shown to be effective at gathering in the past. This will allow for future projects to build upon existing accomplishments rather than repeating past research.

5.2.3 Collaborative Science and Technology Network for Sustainability

We believe that to continue large scale green building research the NCER needs to develop a replacement for the now discontinued CNS program. Since 2004 the CNS program was NCER's cornerstone for sustainability. Unfortunately, 2006 was the last year for a CNS solicitation. Currently the NCER is developing a new strategic goal for green building. With the completion of this document the NCER will seek to request designated funding for this newly developed goal. Potentially a new program could emerge and become the new forefront for NCER's move toward sustainability and thus green building.

References

ACEEE. (2008, September 20). *ACEEE*. Retrieved September 20, 2008, from http://aceee.org

Billatos, S. B., & Basaly, N. A. (1997). *Green Technology and Design for the Environment.* Washington: Taylor & Francis.

Boulder Green Building. (2008). *Green Building*. Retrieved September 15, 2008, from http://www.greenbuilding.com

Boutwell, S. (2008, June 24). *Adoption of Green Technologies in the Buildings/Facilities Sector: A Market Perspective.* Retrieved September 25, 2008, from AECbytes: http://www.aecbytes.com/viewpoint/2008/issue_39.html

Chiras, D. D. (2004). *The New Ecological Home : A Complete Guide to Green Building Options.* White River Junction, Vermont, United States of America: Chelsea Green Publishing Company.

Coffman, L. S., & Clar, M. L. (2003). Low-Impact Development: An Ecologically Sensitive Alternative for Stormwater Management. In R. Field, & D. Sullivan, *Wet-Weather Flow in the Urban Watershed: Technology and Management* (pp. 271-294). Boca Raton: CRC Press.

ECY. (2008, September 25). *Washington State Department of Ecology.* Retrieved September 25, 2008, from http://www.ecy.wa.gov/

Environmental Services City of Portland. (2006, November). *Ecoroof Fact Sheet.* Retrieved November 12, 2008, from http://www.portlandonline.com/shared/cfm/image.cfm?id=195199

Environmental Services City of Portland. (2006, November). *When it falls on the roof.* Retrieved November 12, 2008, from http://www.portlandonline.com/bes/index.cfm?c=43110&a=129056

Environmental Services City of Portland. (2006, November). *When it gets to ground.* Retrieved November 12, 2008, from http://www.portlandonline.com/bes/index.cfm?c=43110&a=129057

Florida Solar Energy Center. (2008). *Florida Solar Energy Center*. Retrieved September 25, 2008, from http://www.fsec.ucf.edu/en/

Fox, A. (2008, September 10). *Green building basics: Roofs and water management*. Retrieved September 19, 2008, from http://salemnews.com/pulife/local_story_253222725.html

Grigg, N. S. (2003). *Water, Wastewater, and Stormwater Infrastructure Management.* Boca Raton: CRC Press.

Healthwise. (2007, November 1). *Environmental Illness - Overview*. Retrieved September 20, 2008, from http://www.webmd.com/allergies/tc/environmental-illness-overview

Hong, T., Chou, S. K., & Bong, T. Y. (2000). *Building Simulation: an overview of developments and information sources.* Singapore: Department of Mechanical and Production Engineering, National University of Singapore.

Institute for Environmental Security. (2008). *Institute for Environmental Security*. Retrieved September 14, 2008, from http://www.envirosecurity.org/

James, J. P., & Yang, X. (2006). Emissions of Volatile Organic Compounds from Several Green and Non-Green Building Materials: A Comparison. *Indoor and Buiilt Environment* (14), 69-74.

Kats, G. (2003). *The Costs and Financial Benefits of Green Buildings.* Westborough: Massachusetts Technology Collaborative.

Lockwood, C. (2008, May). The Blue-Collar Green-Building Boom. *Harvard Business Review* , 50-53.

Ludwig, A. (2006). *Create an Oasis with Grey water Choosing, Building and Using Grey water Systems — Includes Branched Drains* (5 ed.). New York, NY: Oasis Design.

US Census Bureau. (2001). *American Housing Survey.* Retrieved November 12, 2008, from http://www.census.gov/hhes/www/housing/ahs/ahsfaq.html

US DOE. (2008). *Department of Energy*. Retrieved October 5, 2008, from http://www.energy.gov/

US EPA. (1995). *1995 Clean Water Needs Survey Report to Congree*. Retrieved September 27, 2008, from http://www.epa.gov/owm/mtb/cwns/1995rtc/toc.htm

US EPA. (2004, December 20). *Buildings and the Environment: A Statistical Summary*. Retrieved September 15, 2008, from http://www.epa.gov/greenbuilding/pubs/gbstats.pdf

US EPA. (2008a). *About EPA*. Retrieved September 20, 2008, from http://www.epa.gov/epahome/aboutepa.htm

US EPA. (2008b). *EPA Green Building*. Retrieved September 10, 2008, from http://www.epa.gov/greenbuilding

US EPA. (2008c). *Funding Opportunities*. Retrieved September 25, 2008, from http://www.epa.gov/greenbuilding/tools/funding.htm

US EPA. (2008d). *2006-2011 EPA Strategic Plan.* Retrieved September 15, 2008, from www.epa.gov/ocfopage/plan/2006/entire_report.pdf

US EPA NCER. (2008, August 7). *NCER*. Retrieved September 16, 2008, from http://es.epa.gov/ncer/about/

USGBC. (2008a). *Green Building Facts.* Retrieved November 13, 2008, from http://www.usgbc.org/ShowFile.aspx?DocumentID=3340

USGBC. (2008b). *LEED*. Retrieved September 10, 2008, from http://www.usgbc.org/DisplayPage.aspx?CategoryID=19

Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Science Direct , 35* (5), 2683-3120.

WPI. (2007, May 15). *Interactive Qualifying Project*. Retrieved October 13, 2008, from http://www.wpi.edu/Academics/Depts/IGSD/iqp.html

Yudelson, J. (2008). *The Green Building Revolution.* Washington, DC: Island Press.

Appendices

Appendix A: Sponsor Description

The Environmental Protection Agency

The Environmental Protection Agency (EPA) was founded as an independent agency under the Clean Air Act during President Nixon's term in 1970 (US EPA, 2008a). Its mission is to protect the environment and human health through developing environmental policies and regulations. The EPA has to perform its mission while maintaining the nation's economic competitiveness.

The current EPA administrator, Stephen L. Johnson, has a strong scientific background in biology and environment (US EPA, 2008a). Since becoming the head of EPA, he has implemented many significant environmental programs and enforced the nation's environmental laws.

The EPA has 5 goals as outlined in its Strategic Plan 2006-2011, which is a five-year plan to deliver a cleaner and healthier environment for the public(US EPA, 2008d). Its goals include having "clean air, clean and safe water, land preservation and restoration, healthy communities and ecosystems, and compliance and environmental stewardship."(p. 5)

The structure of the EPA consists of a head administrator and a deputy administrator who are responsible for the monitoring of the nine assistant administrators, three offices, and ten regions that form the EPA (US EPA, 2008a). The nine assistant administrators are in charge of Administration and Resource Management, Air and Radiation, Enforcement and Compliance Assurance, International Affairs, Environmental Information, Prevention Pesticides and Toxic Substances, Research and Development, Solid Waste and Emergency Response, and Water. The three offices consist of the Chief Financial Officer, the General Counsel, and the Inspector General. The ten regions that contain EPA offices are Boston, New York, Philadelphia, Atlanta, Chicago, Dallas, Kansas City, Denver, San Francisco, and Seattle. The organizational chart is shown in the figure below.

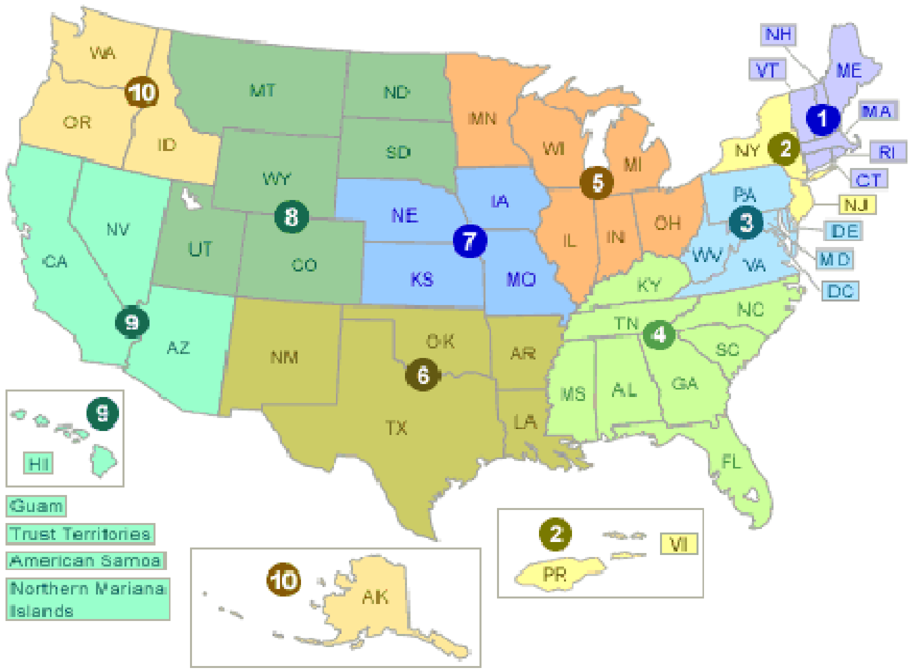


Figure A-1: EPA Regional Office Map

The Boston region, EPA New England, has its own Regional Administrator and Deputy Regional Administrator (US EPA, 2008a). They are responsible for six areas of interest within the region. These areas are Environmental Stewardship, Administration and Resource Management, Regional Counsel, Ecosystem Protection, Environmental Measurement and Evaluation, and Site Remediation and Restoration.

Figure A-2: EPA Organization's structure (U.S. EPA, 2008a)

The EPA strategic plan is divided into five different focus areas (US EPA, 2008d). Each focus area is allocated a certain percentage of the total available resources. These descriptive divisions allow straightforward placement of projects and jurisdictions. Our project has been identified as fitting into goal 5 of the EPA, known as the Compliance and Environmental Stewardship division.

The EPA is a federally funded agency with an annual budget that must be split between the 5 divisions of the EPA (US EPA, 2008d). As of 2007 the EPA had a total budget of 7.32 billion dollars. Of this money 734 million went to goal 5 of their strategic plan, roughly 10% of the total. It is worth noting that this particular division of the EPA is receiving over 9 million dollars less in funding than the previous year. Furthermore, it is also worth noting that the overall EPA budget has been consistently cut year after year since its height in 2004. A specific place that division 5 puts money is in grants to states and communities. With these funds they are obligated to provide technical assistance, education and outreach to assist businesses and industries in identifying strategies and solutions to reduce wastes and pollution at the source.

As of 2007, the EPA employed 17,560 full time individuals (US EPA, 2008a). Of these, there are roughly 3,480 devoted to strategic goal 5 of the EPA. Although this section of the EPA receives 10% of the total budget, it does comprise nearly 20% of the workforce.

Evaluating problems and enacting solutions are only two of the resources the EPA can utilize (US EPA, 2008d). Power of the enacted policies is critical to the EPA's mission of protecting the environment. On a basic level the EPA works to provide the compliance information to the regulated community. This is partly accomplished on the state level, but also by universities that were given research funds. Monitoring is the next step towards the long-term goal of environmental improvement. A community under regulations is consistently reviewed and evaluated by the EPA, "laws, regulations, permit conditions, and settlement agreements" are carefully monitored (p. 59). Enforcement is a third step towards rehabilitating a community. The EPA works with the

Department of Justice to ensure compliance of legislation, should the need arise. Outside of the EPA's power is its desire for a regulated community to take initiative and use self-evaluation to ensure compliance. The EPA works to partner with other federal organizations along with the state and lower levels of the government to ensure the mission of the EPA is fulfilled.

Technology is essential for solving the complex issue of safeguarding both human health and the environment. The EPA has a strong focus on partnering with industry (US EPA, 2008d). The 2007 budget outline highlights that the "EPA will continue to reduce the amount of toxic chemicals in use by encouraging the design of alternative less toxic chemicals and industry processes through its Green Chemistry and Green Engineering Programs" (p. 61).

Under Division 5 of the EPA is a program known as Performance Track (US EPA, 2008d). The growing success of this program is attributed to the incentives to participate. The EPA "recognizes and rewards private and public facilities that demonstrate environmental stewardship" beyond the current requirements (p. 63).

Other than the EPA, there are other organizations that deal with the environment and human health. These organizations work around the world fulfilling missions like the EPA's. The Institute for Environmental Security (2008) is an international non-profit organization established to bring political attention to environmental security. The UN has several sub-groups that manage environmental concerns such as the United Nations Environment Organization (UNEO, 2008) and the United Nations Environment Programme (UNEP, 2008). In Europe, the European Environment Agency (EEA) deals with environmental issues. The EEA is an agency of the 27 countries in the European Union as well as Iceland, Norway, Liechtenstein, Turkey and Switzerland (EEA, 2008). Another environmental agency is the Commission for Environmental Cooperation (CEC, 2008), which was created by the USA, Canada and Mexico to address environmental concerns, promote effective enforcement of environmental law and help prevent potential trade and environmental conflicts.

There are also a lot of private agencies that help with environmental problems. Greenpeace is one such organization. It deals with issues such as commercial whaling, nuclear testing … around the world (Greenpeace, 2008). Another private agency is the Environmental Investigation Agency (2008), which investigates crimes against wildlife and the environment. There are many more such agencies such as Earth Policy Institute, Birdlife International, and World Conservation Union.

Some of these organizations collaborate with the EPA in order to protect human health and the environment. The Centers for Disease Control (CDC) works with the EPA as well as the Boston Public Health Commission to reduce emissions from the auto shops in low-income neighborhoods (CDC, 2008). However, most of these groups, while they may not be collaborating with the EPA, are not in competition with the EPA.

The National Center of Environment

The WPI team's project is sponsored by the National Center for Environment Research (NCER) of the EPA, one of the seven research organizations inside the Office of Research & Development (ORD) of the EPA. NCER's mission is to support high-quality research by the nation's leading scientists that will improve the scientific basis for national environmental decisions (US EPA NCER, 2008). NCER and ORD mirror the National Academy of Sciences' risk assessment paradigm by focusing research on: Exposure, Effects, Risk Assessment, and Risk Management. NCER supports leading edge, extramural research in each of these areas through competitions for grants, fellowships, and innovative small business research contracts.

Appendix B: NCER Grant Programs

NCER funds are given to recipients who applied for and won a solicitation pertaining to a specific field of research. There are three main programs that NCER funds: P3, CNS, and SBIR. Each program has specific criteria that applicants must consider when drafting a proposal.

Small Business Innovative Research Program

SBIR or Small Business Innovation Research is an annual program that focuses on the development of innovative environmental technologies and products. Solicitations begin annually in March and typically last till December. A proposal selected for Phase I funding can receive up to 70,000 dollars. Upon the successful completion of Phase I of the project a recipient can apply for a Phase II to continue development of their project. Phase II grants are up to 225,000 dollars.

Collaborative Science and Technology Network for Sustainability Program

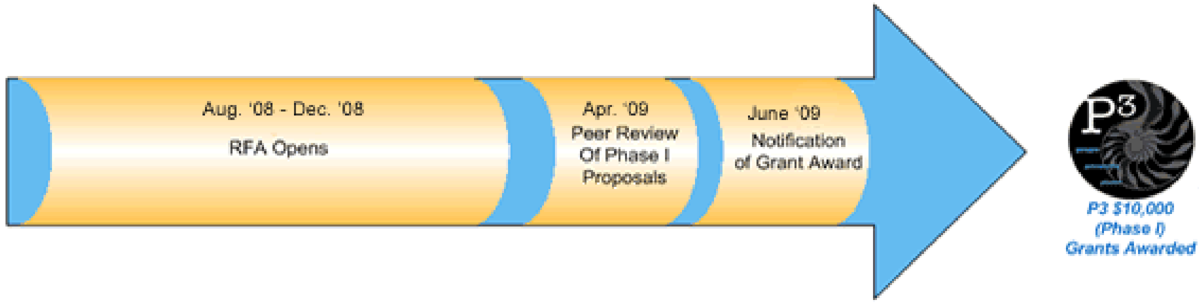
The Collaborative Science and Technology Network for Sustainability (CNS) grant program was launched in 2004 as the foundation for NCER's move toward sustainability research. Under this program 10 major projects have been funded dealing with developing and promoting sustainable practices.

CNS projects often target to make large-scale impacts. Projects in the past have partnered with universities, federal agencies, cities, states, regional planning organizations, nonprofit organizations and industry.

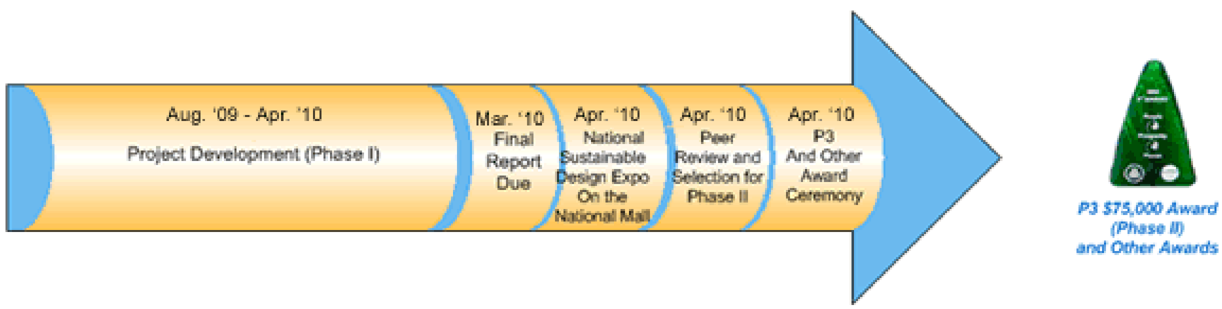
People, Prosperity and Planet Program

The People, Prosperity, and Planet program (P3) is a yearly grant competition for undergraduate students and their respective faculty. The P3 program is currently in its 6th year of solicitations. The following three figures show the grant process from start to finish.

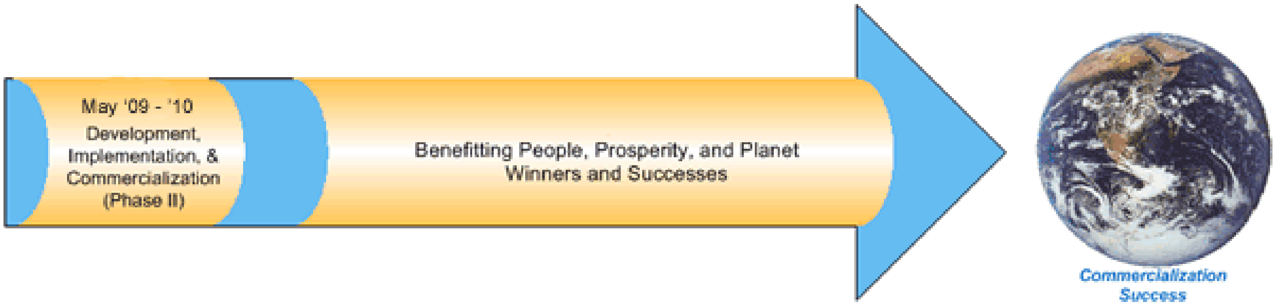
The competition begins with an RFA opening. These RFA's fall under one of the following categories: Agriculture Materials and Chemicals, Energy, Information Technology, Water, or Built Environment. As seen in Figure below, the projects then go into a peer review process where approximately 50 P3 grants will be selected for funding. Phase I is an award of not more than 10,000 dollars.



After a project has been selected for a Phase I P3 grant there is a disperse period prior to the oncoming academic year. The grantees are given one year to complete and produce a final report. All of the grant winners for that year then attend the National Sustainable Design Expo held annually on the National Mall grounds in DC. There the projects participate in another peer review where they have the chance to be selected for Phase II funding of up to 75,000 over two years. Phase II funding is targeted at further developing Phase I results in to a product that could be deployed into the public market.



If a project is one of the approximately six Phase II winners they are given a minimum of one year to complete their project. Ultimately the goal of Phase II is to develop a product that will be a commercial success and that will fulfill the goals of the P3 program.


May '09 - '10
Development, Implementation, & Commercialization (Phase II)
Benefitting People, Prosperity, and Planet
Winners and Successes
Commercialization Success

Appendix C - WPI East Hall Green Dormitory Interview

Architect Lynne Deninger

Interviewees	Architect Lynne Deninger
WPI attendants	Manh-Hung Le (Chair), Brian Robie (Secretary)
Topic	Green Building

<u>Interviewees Background</u>

Ms. Deninger is the architect of the East Hall dormitory at WPI, which received LEED Gold Certification.

Tuesday, October 1, 2008 @ 11:15 AM

1. In general, is East Hall more efficient, regarding energy and water, than other buildings on campus?

- East hall is 31% more efficient than a conventional building of the same size and occupancy.
- East hall contains high efficiency heating and cooling systems

2. Did you use any unique design elements which are different from conventional technologies?

- Yes, the air coolers on East Hall are very rare, approximately one of eight in the country.
- Fins were also added to the exterior of the building that were designed to shade most of the windows during the summer months, cutting down the energy needed to cool the building immensely
- Allowed for a smaller cooling system to be used

3. Did you implement a green roof?

- Yes, East Hall has a green roof with active monitors to record water data such as amount, temp, and quality.

4. How well does East Hall meet or exceed the green building standards of LEED?

- East Hall is currently in the stages of certification by LEED, the expected outcome is a high silver or low gold certification.

5. Did cost affect the extent of going green?

- Yes, we designed East Hall to be as energy efficient as possible while considering the budget given to us.

6. Were there green technologies that you were unable to include in the building?

- Yes, the use of alternative energy was eliminated as a possibility due to the high costs and relatively low returns in this region
- Recycled water was also eliminated as there are multiple constraints placed upon recycled water by the state of Massachusetts.

7. What criteria were considered when designing for water and wastewater management? Are there any methods of wastewater treatment?

- East Hall has a goal of zero stormwater runoff.
- Site contains water retention systems and a green roof
- The building contains no water treatment system

8. Are there any wastewater or water problems that exist within the building?

- At this time there are no problems that have developed, the building is still relatively new

9. Did you use water efficient utilities that the EPA supports, such as green faucets or toilets?

- Yes, all facilities in East Hall are water efficient.

Other interesting points:

- Landscaping is self-sustaining, there is no irrigation system
- Lighting energy consumption is less than one watt per square foot
- The heating units only operate independently of each other and only as needed
- Rooms contain occupancy sensors that automatically minimize the heating and cooling systems when the rooms are vacant for more than 12 hours
- Windows have sensors to shut off heat or cooling when opened

Professor Paul P. Mathisen

Interviewees	Professor Paul P. Mathisen
WPI attendants	Manh-Hung Le (Chair), Brian Robie (Secretary)
Topic	Stormwater Management

Interviewees Background

Professor Paul P. Mathisen is currently a professor in the Civil Engineering Department at WPI who concentrates on Environmental Engineering and Water Resources

---

Tuesday, October 3, 2008 @ 11:15 AM

1. What methods does East Hall use to keep stormwater to a minimum?

The building incorporates pervious landscaping around the sides of the building. There is also the green roof.

2. The East Hall architect mentioned that the building has zero runoff. Does zero runoff mean the water retention rate is 100% or the water pollutant is completely filtered?

It is unlikely to have 0% stormwater runoff. Often the most effective method for minimizing stormwater runoff is to delay its release by incorporating storage containers.

3. What impurities can be found in the stormwater? Is the stormwater treated before discharged to municipal sewer?

The stormwater quality should be of fairly good quality. There are no chemicals used on site.

4. Are there any additional methods used besides a green roof?

The use of stormwater storage would prevent potential flash flooding. Another area is porous pavement

5. Is there anything besides costs preventing green buildings from become more widespread?

Inconvenience possibilities: low water flow (toilets, showers, sinks), space limitations, aesthetic perception.

6. Do green building wastewater management systems have any the environmental impacts of the surrounding areas?

Any building whether green or not will have an impact on the surrounding environment. Stormwater runoff can be detrimental to the surrounding areas, especially during sudden downpours.

7. Could you comment on what areas you think the EPA should focus on in regards to green buildings, especially to water management system?

- Stormwater management, especially in relation to storing the water and preventing immediate discharge.
- Ways of getting more green roofs on current buildings.
- Energy efficiency
- Reuse of water, especially useful in southern states where water shortage is often a problem in the summer months.

Appendix D – NCER Green Building Research List

EPA ID	TITLE	Site Specific	Commercial	Residential	Regional	General	Multimedia	Wastewater	Reuse	Pretreatment	Stormwater	Green roof	Watershed	Others	Water efficiency	Energy Efficiency	Material	Indoor Air	Sustainability	Technologies	Performances Metrics	Implementation	Social Acceptance	GRANT	PROGRAM
R833345	Mapping Regional Development for Smart Growth Planning to Minimize Degradation of Water Quality and Enhance Green Infrastructure				1														1		1	1		$249,919	CNS
R833362	Energy, Water, and Land Use: A Framework for Incorporating Science into Sustainable Regional Planning				1														1		1	1		$299,220	CNS
X3832207	Using Market Forces to Implement Sustainable Stormwater Management				1						1			1					1		1	1		$288,000	CNS
R833347	Testing Sustainable Building Materials and Practices during Gulf Coast Reconstruction				1												1				1	1		$295,970	CNS
X3832206	Ecological Sustainability in Rapidly Urbanizing Watersheds: Evaluating Strategies Designed to Mitigate Impacts on Stream Ecosystems				1						1		1						1		1	1		$278,626	CNS
X3831781	Framework for Sustainable Watershed Management				1						1		1						1		1		1	$102,500	CNS
R833346	Reality Check Plus: Envisioning a Sustainable Maryland				1		1												1		1		1	$274,060	CNS
X3832204	Multi-Objective Decision Model for Urban Water Use: Planning for a Regional Water Reuse Ordinance				1			1	1										1	1		1		$255,000	CNS
U915926	Optimization of the Design of Constructed Wetlands Used for the Treatment of Municipal Wastewater in Semi-Arid Regions of the United States and the World				1			1		1										1		1		$84,130	Fellowship
FP916374	Evaluation of Environmental and Health Benefits of Ecological Infrastructure for Urban Heat Island Mitigation				1														1		1	1		$111,344	Fellowship
U915186	Ecological Design in Architectural Practice					1													1		1	1		$102,000	Fellowship
U915346	Community-Based Environmental Planning and Urban Economic Development				1														1		1	1		$102,000	Fellowship
FP916981	Building Sustainable Social Infrastructures in Communities				1														1		1	1		$0	Fellowship
U915591	Urban Form and Thermal Efficiency: How the Design of Cities Can Influence the Urban Heat Island Effect	1		1												1				1		1		$64,576	Fellowship

EPA ID	TITLE	Site Specific	Commercial	Residential	Regional	General	Multimedia	Wastewater	Reuse	Pretreatment	Stormwater	Green roof	Watershed	Others	Water efficiency	Energy Efficiency	Material	Indoor Air	Sustainability	Technologies	Performances Metrics	Implementation	Social Acceptance	GRANT	PROGRAM
U915549	Evaluation of Hydrologic and Water Quality Benefits of Infiltration-Based Urban Stormwater Management					1					1			1						1		1		$80,316	Fellowship
U916173	Spatial Analysis of Monitoring Designs and Watershed Characteristics Affecting Nonpoint Source Runoff					1					1			1							1	1		$89,793	Fellowship
F6C40889	A Cost-Benefit Analysis of Public Incentives of Private Enterprise Investment in Sustainable Urban Development					1													1		1		1	$74,172	Fellowship
U915402	Environmental and Economic Implications of Landscaping Policies in the Research Triangle Region of North Carolina				1		1														1	1		$29,750	Fellowship
EM833072	The Green Renovation and Expansion of the Aiken Center: A Sustainable Green Building Design, Collaborative Planning Process and Long-Term Demonstration and Research Project	1	1				1														1	1		$867,800	Others
R828626	Introducing Markets for Green Products: Product Demand, Environmental Quality & Economic Welfare					1										1					1		1	$68,042	Others
R827450	Infrastructure Systems, Services, and Climate Change: Integrated Impacts and Response Strategies for the Boston Metropolitan Area				1														1		1		1	$899,985	Others
R829598	Material Selection in Green Design and Environmental Cost Analysis					1											1			1		1		$325,000	Others
SU833564	Reducing the Waste Stream: Bringing Environmental, Economical, and Educational Composting to a Liberal Arts College	1	1				1													1		1		$10,000	P3
SU833555	Development and Monitoring of a Sustainable Affordable Housing Community in Southwest Florida Gulf Coast University	1		1			1														1	1		$9,985	P3
SU833190	The Chameleon House: an Adaptive Sustainable Manufactured Home	1		1												1					1	1		$10,000	P3
SU832501	The DELTA Smart House: Cross-Disciplinary Projects within the Design Framework of Sustainable Construction	1	1				1														1	1		$10,000	P3
SU833515	Social Feasibility of Energy-Efficiency Retrofits and Educational Campaigns for Sustainable Energy Use in Pre-existing College Residence Halls	1	1													1					1		1	$10,000	P3

EPA ID	TITLE	Site Specific	Commercial	Residential	Regional	General	Multimedia	Wastewater	Reuse	Pretreatment	Stormwater	Green roof	Watershed	Others	Water efficiency	Energy Efficiency	Material	Indoor Air	Sustainability	Technologies	Performances Metrics	Implementation	Social Acceptance	GRANT	PROGRAM
SU833558	Green Retrofitting Residential Buildings	1		1			1														1	1		$10,000	P3
SU832510	The Green Dorm: A Sustainable Residence and Living Laboratory for Stanford University	1	1												1	1					1	1		$10,000	P3
SU833201	The Green Dorm: A Sustainable Residence and Living Laboratory for Stanford University	1	1												1	1					1	1		$75,000	P3
SU833802	The Learning Barge: Environmental + Cultural Ecologies on the Elizabeth River	1	1					1	1							1					1		1	$75,000	P3
SU831857	The Evergreen Roof Project: Standards, Methods and Software for Evaluating Living Roof Systems				1						1	1									1		1	$9,966	P3
SU833529	Standalone Green Community-Center Buildings: Hydrogen Generation/Storage/Delivery System for when Primary Energy Storage is at Capacity	1	1													1				1		1		$10,000	P3
SU833192	Designing and Demonstrating Sustainable Multi-Family Attached Housing	1		1			1													1		1		$10,000	P3
SU833561	Architecture as Pedagogy: Interdisciplinary Design and Creation of a Carbon Neutral Idaho Environmental Learning Center at the University of Idaho McCall Field Campus	1	1				1														1	1		$10,000	P3
SU831873	Fostering Sustainability: Designing a Green Science Building at a Small Maine College	1	1				1														1	1		$6,623	P3
SU832505	EVALUATING ecoMOD: Building Performance Monitoring and Post-Occupancy Evaluation of an Ecological, Modular House	1		1			1														1	1		$10,000	P3
SU832498	Application of Bioretention, Native Plants and Other Low Impact Stormwater Management Strategies to Tufts University	1	1								1			1						1		1		$9,444	P3
SU831855	Sustainable Modular Panelized System: Reinventing the Building Industry					1	1													1			1	$10,000	P3
SU832466	Developing and Assessing the Impact of a Socio-Technological Resource-Use Feedback System for Improving the Environmental Performance of Buildings and Institutions	1	1													1					1		1	$74,991	P3
SU831875	Developing and Assessing the Impact of a Socio-Technological Resource-Use Feedback System for Improving the Environmental Performance of Buildings and Institutions	1	1													1					1		1	$9,993	P3

EPA ID	TITLE	Site Specific	Commercial	Residential	Regional	General	Multimedia	Wastewater	Reuse	Pretreatment	Stormwater	Green roof	Watershed	Others	Water efficiency	Energy Efficiency	Material	Indoor Air	Sustainability	Technologies	Performances Metrics	Implementation	Social Acceptance	GRANT	PROGRAM
SU832507	Moving Towards a Sustainable Campus: Design of a Green Roof Monitoring Experiment	1	1								1	1									1	1		$10,000	P3
SU831881	City in a Box: A New Paradigm for Sustainable Living - **P3 STUDENT DESIGN**				1											1			1		1	1		$10,000	P3
SU831826	Civic Stormwater Gardens: An Ecological Solution for Cities with CSOs					1					1			1						1		1		$10,000	P3
SU833545	Enhanced Nutrient Removal from On-Site Wastewater Treatment Systems					1		1		1										1		1		$10,000	P3
SU831827	A Decision Support Tool for Sustainable Urban Water Management				1			1		1	1			1					1		1	1		$10,000	P3
SU832511	Transforming the University Campus into a Sustainable Community: An Evaluation of Land Use, Smart Growth, and Sustainability at the University of Michigan	1	1																1		1	1		$10,000	P3
SU831874	Lowertown: A Collaborative Effort in Sustainable Urban Redevelopment				1														1		1		1	$10,000	P3
SU833559	Sustainable Overlay District (SOD) Methodology				1														1		1		1	$10,000	P3
SU833193	Interactive Planning Tool for Sustainable Urban Planning in a Built, Urban Community					1													1	1			1	$10,000	P3
SU832502	Enhancing Sustainability by Spinning Green into a Grey Infrastructure: The Design of Parks and Greenways in a Community's Fabric					1													1	1			1	$9,952	P3
SU832489	Whole systems, Integrated Site design for Education (WISE) Website: An Interactive Website for Educators and Students					1	1														1		1	$10,000	P3
SU831882	Adoption of Alternative Energy Sources in Chico, CA: Facilitating an Action Plan					1										1				1		1		$9,455	P3
SU831880	Using An Impervious Permit" Allowance System To Reduce Impervious Surface Coverage for Environmental Sustainability"					1					1			1						1		1		$8,269	P3
SU831895	Accurate Building Integrated Photovoltaic System (BIPV) Architectural Design Tool					1										1				1		1		$7,066	P3
SU833556	A Stormwater Constructed Wetland Using Renewable and Recyclable Materials and Native Wetland Plants					1					1			1						1		1		$9,968	P3
SU832496	Stormwater Management in Highland Park Borough: The Next Step in a Sustainability Plan				1						1		1						1	1		1		$10,000	P3

EPA ID	TITLE	Site Specific	Commercial	Residential	Regional	General	Multimedia	Wastewater	Reuse	Pretreatment	Stormwater	Green roof	Watershed	Others	Water efficiency	Energy Efficiency	Material	Indoor Air	Sustainability	Technologies	Performances Metrics	Implementation	Social Acceptance	GRANT	PROGRAM
SU833552	Developing a Small Business in Response to a Stormwater Utility for the New Jersey Meadowlands				1						1			1						1		1		$10,000	P3
SU832493	Rainwater Harvesting: A Simple Means of Supplementing California's Thirst for Water - **P3 RECYCLE PROJECT**				1						1			1						1		1		$10,000	P3
SU831879	Beyond Green Buildings: An Integrated Holistic Design Approach					1	1														1		1	$10,000	P3
SU831854	Healthy and Energy-Efficient Housing in Hot and Humid Climates: A Model Design	1		1												1		1		1			1	$10,000	P3
SU833557	Development, Design and Consumer Testing of Marketable Residential LED Light Luminaires					1										1				1		1		$9,535	P3
SU831869	Greening Standards for Green Structures: Process and Products				1														1		1	1		$9,998	P3
SU832512	Growing Alternative Sustainable Buildings: Bio-composite Products from Natural Fiber, Biodegradable and Recyclable Polymer Materials for Load-bearing Construction Components					1											1			1		1		$10,000	P3
SU833951	Implementation of Green Roof Sustainability in Arid Conditions				1						1	1								1		1		$8,915	P3
SU832504	Zero Infrastructure Stormwater Management					1					1			1							1	1		$9,894	P3
SU833566	Place-Based Green Building: Integrating Local Environmental and Planning Analysis into Green Building Guidelines					1													1		1	1		$10,000	P3
SU833188	Enhanced Sustainability through Straw-Bale Construction: Education-Research Building Demonstrating How to Live Sustainably in the Midwest				1														1	1		1		$10,000	P3
SU831856	Sustainable Housing at Pine Ridge Reservation	1		1			1													1		1		$10,000	P3
SU831810	Waste to Value: Incorporating Industrial Symbiosis for Sustainable Infrastructure				1														1	1		1		$10,000	P3
SU831878	Smart Windows for Smart Buildings					1										1				1		1		$10,000	P3
SU833940	Permeable Parking: A Green Approach to Managing Water Runoff at the University of St. Francis - **GRAY WATER RECYCLE**	1	1								1			1						1		1		$10,000	P3
SU833565	The Cast Paper Dome: An Opportunity to Develop New Materials and Construction Techniques for Sustainable Building					1											1			1		1		$10,000	P3

EPA ID	TITLE	Site Specific	Commercial	Residential	Regional	General	Multimedia	Wastewater	Reuse	Pretreatment	Stormwater	Green roof	Watershed	Others	Water efficiency	Energy Efficiency	Material	Indoor Air	Sustainability	Technologies	Performances Metrics	Implementation	Social Acceptance	GRANT	PROGRAM
SU831822	Eco-Wall Systems: Using Recycled Material in the Design of Commercial Interior Wall Systems for Buildings					1											1			1		1		$9,995	P3
SU832477	High Albedo and Environment-Friendly Concrete for Smart Growth and Sustainable Development					1											1			1		1		$10,000	P3
SU833202	Growing Alternative Sustainable Buildings: Biocomposite Products from Natural Fiber, Biodegradable and Recyclable Polymer Materials for Load-bearing Construction Components					1											1			1		1		$75,000	P3
SU831877	Zero Net Energy Homes Project	1		1												1					1	1		$10,000	P3
SU833563	Paving the Way to a “Greener” Campus: Alternative Paving Materials for Pollution Control and Aesthetic Appeal	1	1								1			1			1			1		1		$10,000	P3
SU831830	Engineered Stormwater Management for Low-Income Urban Communities				1						1		1							1		1		$10,000	P3
SU833194	Regionally Appropriate Sustainable Design: Urban Green Roof Applications for Temperate Continental Climates				1						1	1				1					1	1		$10,000	P3
SU833189	Optimizing Green Roof Technologies in the Midwest				1						1	1									1	1		$10,000	P3
SU833187	GREEN KIT: A Modular, Variable Application System for Sustainable Cooling					1										1					1	1		$10,000	P3
EPD06039	HybridAir: An Integrated Ventilation, Vapor Compression, and Indirect Evaporative Cooling System					1										1		1		1		1		$69,988	SBIR
68D02089	Wastewater Treatment by Pulsed Electric Field Processing					1		1		1										1		1		$99,092	SBIR
68D03065	Development of New Wastewater Infrastructure Systems With Enhanced Durability and Structural Efficiency				1			1		1							1			1		1		$225,000	SBIR
EPD05012	Streamlining Green Building Design: Developing Requirements for the Sustainable Design Suite					1	1														1	1		$70,000	SBIR
EPD06078	Streamlining Green Building Design: Developing the Sustainable Design Suite					1	1														1	1		$225,000	SBIR
EPD08035	Green Product-Service System Authentication and Registry Service for the Building Industry					1	1														1	1		$69,556	SBIR
EPD06054	An Integrated Ecoroof Energy Analysis Model					1					1	1									1		1	$69,856	SBIR

EPA ID	TITLE	Site Specific	Commercial	Residential	Regional	General	Multimedia	Wastewater	Reuse	Pretreatment	Stormwater	Green roof	Watershed	Others	Water efficiency	Energy Efficiency	Material	Indoor Air	Sustainability	Technologies	Performances Metrics	Implementation	Social Acceptance	GRANT	PROGRAM
EPD04041	Cement-Polymer Composites From Recycled Polymers for Construction					1											1			1		1		$70,000	SBIR
EPD07039	Biodegradable Thermoplastic Natural Fiber Composite					1											1			1		1		$70,000	SBIR
68D02100	Upflow Filters for the Rapid and Effective Treatment of Stormwater at Critical Source Areas					1					1			1						1		1		$99,926	SBIR
68D03068	Upflow Filter for Rapid and Effective Treatment of Stormwater at Critical Source Areas					1					1			1						1		1		$225,000	SBIR
EPD04050	Stormwater Flow Control Device					1					1			1						1		1		$70,000	SBIR
EPD05055	Stormwater Flow Control Device					1					1			1						1		1		$224,797	SBIR
TOTAL		**26**	**17**	**9**	**30**	**39**	**18**	**7**	**2**	**5**	**27**	**6**	**4**	**17**	**2**	**20**	**11**	**2**	**25**	**45**	**50**	**76**	**19**	**$7,379,467**	

Appendix E – NCER Principle Investigators Interview

Principle Investigator Interview Protocol Form

Project:
Contact person:
Contact number:

Set interview appointment by phone

Good (morning / afternoon), my name is ______________. I am working as a student intern from Worcester Polytechnic Institute (WPI). Our team is working for the EPA NCER on a project concerning green building and more specifically *(stormwater management / water recycling)*. We would like to do an interview with the project investigators of the project ____project name___ that received funding from the EPA (STAR / SBIR / P3) program in ____year___. Can you put me in touch with ____PI's name___, who was the principle investigator of the research or another person who is knowledgeable about the project?

... (Wait until the call is transferred to the PI and repeat the introductory script above)

We would like to set an appointment at your convenience to have an interview conference call. Would you like a copy of our interview agenda prior to the interview?

Interview Script

I. Introduction

We are students from Worcester Polytechnic Institute working on a project at the EPA NCER. We are working on identifying the research gaps in green building technologies and their impacts on water infrastructure systems.

We found your project to be relevant to us when we were evaluating past NCER research funding. We wanted to get further information related to this project.

II. Questions

Preliminary

1. Could you tell us more about your project and why did you see a need for your project?
2. Could you tell us about the most interesting lessons and surprising results about your project?
3. How does the regulatory climate affect your project?

Technology

4. How does it tie in with green building and/or water infrastructure systems?
5. What were the technology needs and information gaps that were uncovered by your research result?

Implementation

6. Did you consider commercialization for your research result? If so, how would you envision your product in the market and the challenges it would face? Who would be your primary customers?.
7. Where has your research result been applied? What is the current scale of implementation of your technology? What are the barriers for expansion?

Future Focus

8. What furthered work has you inspired?
9. Do you have current project ideas related to green building that need funding?
10. Where should future green building research focus, both in your area and more broadly?

Funding

11. Did you receive funding from other sources for related work?

Additional questions if applicable

12. Did you modify your research objectives to respond to the EPA solicitation? Would you do the research differently?
13. Do you have any further suggestions for the EPA?

III. Call-Ending

We appreciate you taking your time to complete this interview with us. I'm sure that this information will prove itself to be useful in our final report. We will follow up with you, and send our interview meeting minutes within the next couple of days. Can we contact you with follow up questions, if needed? Thanks again!!

P3 - High Albedo and Environment-Friendly Concrete

Project: High Albedo and Environment-Friendly Concrete for Smart Growth and Sustainable Development

Institution	Period	EPA ID	Grant
Ohio Northern University	October 2005 – September 2006	SU832477	$10,000

Why we chose this project:

This project describes an external factor not inside building, i.e. high albedo as material for sustainability. Through interview this project, we are seeking to understand about the impacts between green building and the surrounding impervious surfaces. This is one of very few material projects related to green building.

Principle Investigators: Dr. Reza Farhad

Interview

1. Could you tell us more about your project and why did you see a need for your project?

There is a lot of surface area covered by pavement. Traditional pavement can cause the heat island effect, where the pavement absorbs solar energy, causing the surroundings to increase in temperature. This decreases the air quality and poses human health risks.

2. Could you tell us about the most interesting lessons and surprising results about your project?

Fly ash is less effective at solar reflection, even though the material is lighter in color. Professor Farhad expected the opposite to be true, where fly ash would be an effective material for solar reflection. However, slag turned out to be a better material, which is what Professor Farhad and his team recommended at the end of their research.

3. How does the regulatory climate affect your project?

There was concern for the pavement materials leeching offsite, becoming a potential environmental concern. There is still research needed to discover any possible detriments to the surrounding areas from using these materials. The government also has limits on the amount of slag/fly ash contained in cement mixtures. This material is impervious and will still cause stormwater runoff.

4. How does it tie in with green building and/or water infrastructure systems?

This particular mixture is still in the development stage but it could be used in a green building. LEED gives points for using these materials because they reduce the urban heat island effect.

5. What were the technology needs and information gaps that were uncovered by your research result?

Further development and implementation of green technologies is needed. More research is needed to determine if any leeching will occur with the cement mixtures and also what amount of slag/fly ash should be the new limit for regulatory concerns.

6. Did you consider commercialization for your research result? If so, how would you envision your product in the market and the challenges it would face? Who would be your primary customers?

Commercialization was envisioned but the product is still in the research and development stages. The private sector would be more willing to accept this technology because the material costs less and will reduce energy consumption of the property. The public sector faces more difficulties such as highways because the material must be proven safe and effective so more research is necessary.

7. Where has your research result been applied? What is the current scale of implementation of your technology? What are the barriers for expansion?

This technology is still in the development stages, therefore this particular mixture of materials is not in use. There are significant barriers, the first being insufficient research. There are regulations that limit the amount of slag/fly ash that can be used at a site without justification for limiting these new technologies.

8. Do you have current project ideas related to green building that need funding?

Not at this time.

9. Where should future green building research focus, both in your area and more broadly?

Reducing the cement consumption is good for everyone and the environment. More broadly, alternative energy such as wind and solar energy should be more researched.

10. Did you receive funding from other sources for related work?

No, the Phase II of this project was also not funded. Phase II would have dealt with implementation, one question was ‘does this more reflective and lighter concrete affect driver performance? And how does the concrete hold up under different conditions as well long term use?’

11. Did you modify your research objectives to respond to the EPA solicitation? Would you do the research differently?

This was a P3 project. We came up with the idea and applied for the funding.

12. Do you have any further suggestions for the EPA?

EPA should focus more on cement because fly ash/slag is a recycled material and will minimize new material consumption. Research and development of alternative energy sources, including wind and solar is also necessary. Future research should also focus on improving the existing technologies such as compressed natural gas.

P3 - Optimizing Green Roof Technologies in the Midwest

Project: Optimizing Green Roof Technologies in the Midwest

Institution	Period	EPA ID	Grant
Southern Illinois University Edwardsville	September 2006 - May 2007	SU833189	$10,000

Principle Investigators: Dr. William Retzlaff (618) 650-2728 wretzla@siue.edu
Dr. Susan Morgan

Interview

November 19, 2008 @ 3:15PM EST

1. Could you tell us more about your project? Why did you see a need for your project?

In 2004, there was a local commercial manufacturing company working on green roof named Green Roof Block. They wanted to evaluate the environmental & material benefits of green roof. About 65 to 80 students have worked on green roof research at the school. The retention rate of rain water on the green roofs is 20-25% in winter and 80% in summer. No heavy metal found in the downstream. The level of nitrates decreases over time as plants develop.

2. Could you tell us about the most interesting lessons and surprising results about your project?

During period of low rainfall, the green roof achieved 80% retention. During dry season with little rain, the plants still grow.

3. How does the regulatory climate affect your project?

Only 14 students are allowed to be on the roof at one time for safety purpose. Otherwise, there are no policies that affected the project.

4. How does it tie in with green building and/or water infrastructure systems?

Omitted

5. What were the technology needs and information gaps that were uncovered by your research result?

Different organic and inorganic medium in Germany were tried but cannot be applied with local climate. Different species of plants were tried. Some work, some don't. Each are is different requiring different types of plant (Dr. Retzlaff and Dr. Morgan recommend a mixture of plants). The biggest selling point is thermal benefit to building. It reduces heating and cooling cost. Data can be found on the website www.green-siue.com

6. Did you consider commercialization for your research result? If so, how would you envision your product in the market and the challenges it would face? Who would be your primary customers?

There are 9 commercialized installation of green roof in the areas. Green roof is promoted by Green roof for Healthy cities of which Dr. Retzlaff is the Vice-President.

7. Where has your research result been applied? What is the current scale of implementation of your technology? What are the barriers for expansion?

It usually requires higher cost for existing building. However, operation benefits can pay off over time. If a new building goes over cost, the green roof is the first thing to be cut.

8. Do you have current project ideas related to green building that need funding?

We are in the process of making a proposal for a green wall research to retain stormwater and heating. University of Texas also has a green roof project. Largest green roof research centers in the nation are Penn. State, Michigan, University of Texas, and North Carolina.

9. Where should future green building research focus, both in your area and more broadly?

Besides green roof, future research should integrate other stormwater management practices.

10. Did you receive funding from other sources for related work?

Donations and funding from industry partners Look at Michigan State Research for Green roof and Retention Pond.

11. Did you modify your research objectives to respond to the EPA solicitation? Would you do the research differently?

Omitted

12. Do you have any further suggestions for the EPA?

The EPA should fund more for green roof research.

P3 - Permeable Parking

Project: Permeable Parking: A Green Approach to Managing Water Runoff at the University of St. Francis

Institution	Period	EPA ID	Grant
University of St. Francis	August 2008 – August 2009	SU833940	$10,000

Principle Investigators: Dr. Salim Diab (815) 740-3855 sdiab@stfrancis.edu

Interview

November 18, 2008 @ 3:15PM EST

1. Could you tell us more about your project? Why did you see a need for your project?

There has been a 5 year old movement for making the campus green named "Greening of Campus" with 9 projects on green roofs and recycling initiatives. In the past three years, the school's recycling has increased to 27 percent of its waste. It started with a grant from Illinois State and this project was an off shoot from this movement and the school's philosophy and mission of environmental stewardship.

2. Could you tell us about the most interesting lessons and surprising results about your project?

The project just recently started so there are no results yet. They anticipate a bit of an issue with getting a good representative sample of cars for their parking lot in order to have good data.

3. How does the regulatory climate affect your project?

So far no regulations have really affected their projects

4. How does it tie in with green building and/or water infrastructure systems?

Omitted

5. What were the technology needs and information gaps that were uncovered by your research result?

None so far as the project is still in the beginning stages

6. Did you consider commercialization for your research result? If so, how would you envision your product in the market and the challenges it would face? Who would be your primary customers?

If the results are sound and innovative, they do consider commercializing, especially if there is as large number of pollutants as they expect going into sewers from runoff. However, the project just started so they have not fully thought about commercialization of results.

7. What areas could your research results be applied? What are the barriers for expansion?

According to Matt D., who is the student leader of the research project, the results could be applied anywhere where pavements are used, especially with the new developments arising in their area. One of the barriers they might face in expansion might be that the permeable pavements may be more expensive than regular pavements.

8. Do you have current project ideas related to green building that need funding?

Not right now

9. Where should future green building research focus, both in your area and more broadly?

No information

10. Did you receive funding from other sources for related work?

They have received some grants from Illinois State, the university as well as City of Julian.

11. Did you modify your research objectives to respond to the EPA solicitation? Would you do the research differently?

Omitted

12. Do you have any further suggestions for the EPA?

EPA should provide more funding for green roof research.

P3 - EVALUATING ecoMOD

Project:	EVALUATING ecoMOD: Building Performance Monitoring and Post-Occupancy Evaluation of an Ecological, Modular House.

Institution	Period	EPA ID	Grant
Auburn University Main Campus.	August 2007-March 2008	SU833566	$10,000

Principle Investigators: John Quale (434) 924-6450

Interview

1. Could you tell us more about your project and why did you see a need for your project?

In 2002 he participated in the Solar Competition sponsored by the DOE. However, some of the ideas were unrealistic and he wanted to work more with affordable housing. The monitoring of the house consists of temperature, humidity, air quality, and energy and water use.

2. Could you tell us about the most interesting lessons and surprising results about your project?

Evaulation is an area where you cant learn from others because there is no significant work done in this area. There are no real world practices. LEED does fully require post-occupancy monitoring.

3. Affordable housing agencies are interested in sustainable housing.

How does the regulatory climate affect your project?

4. There needs to be more incentives, either through taxes or municipalities speeding the process up.
5. How does it tie in with green building and/or water infrastructure systems?

N/A

6. What were the technology needs and information gaps that were uncovered by your research result?

Software tools that integrate into BIN that are useful. This would allow designers, architects, engineers, etc. to find the integrated energy factors. There needs to be greater agreement about life cycle

7. Did you consider commercialization for your research result? If so, how would you envision your product in the market and the challenges it would face? Who would be your primary customers?

Customers are low budget homeseekers. A company did licence it about 2 years ago but little has happened since then. Similar to car industry, the modular industry needs to be pushed forward.

8. Where has your research result been applied? What is the current scale of implementation of your technology? What are the barriers for expansion?
9. What furthered work has you inspired?

Zero energy affordable homes are his long term goal.

10. Do you have current project ideas related to green building that need funding?

He is currently working on the design of his forth project.

11. Where should future green building research focus, both in your area and more broadly?

The development of zero energy affordable homes and then evaluating the performance of these buildings

12. Did you receive funding from other sources for related work?

Yes, around 1.6 million dollars worth of funding from local, regional, and national partners. Companies are willing to help the cause because they are helping students and putting their product into a future use.

13. Did you modify your research objectives to respond to the EPA solicitation? Would you do the research differently?

It is an openended solicitation but the guidelines are ponderious. There seems to be so many guidelines that the judges are overwealmed when it comes to ranking the final product in the competition.

14. Do you have any further suggestions for the EPA?

The built environment is where impacts can be made. There needs to be significant more dollars into these existing structures.

P3 – The DELTA Smart House

Project: The DELTA Smart House: Cross-Disciplinary Projects within the Design Framework of Sustainable Construction

Institution	Period	EPA ID	Grant
Maine Department of Inland Fisheries and Wildlife		R833345	$249,919

Principle Investigators: Jim Gaston (919) 660-5501

Interview

1. Could you tell us more about your project and why did you see a need for your project?

Project idea began with an undergrad electrical engineering senior. After graduation the student stayed and formed a student team to design and develop the smart house. Currently 10 students live in this on campus residence.

2. Could you tell us about the most interesting lessons and surprising results about your project?

Interesting thing is that this is a student initiative and student run project. The construction completed by contractors was the only outside help the students received.

3. How does the regulatory climate affect your project?

City and college regulations and requirements had to be followed. When a design issue came up they went with whatever it took to achieve a LEED platinum score, which was awarded in the summer of 2008.

4. How does it tie in with green building and/or water infrastructure systems?

This is a green building that monitors its energy and soon to be water usage.

5. What were the technology needs and information gaps that were uncovered by your research result?

This house is essentially a living laboratory rather than a house. It has features such as removable wall paneling giving easy access to managing the technology.

6. Did you consider commercialization for your research result? If so, how would you envision your product in the market and the challenges it would face? Who would be your primary customers?

They have only recently even moved into the house. They are still learning and refining the technologies used within the house.

7. Where has your research result been applied? What is the current scale of implementation of your technology? What are the barriers for expansion?

N/A

8. What furthered work has you inspired?

This work is ongoing to improve the efficiency in the house.

9. Do you have current project ideas related to green building that need funding?

Only the continuation of improving the smart house

10. Where should future green building research focus, both in your area and more broadly?

Sustainable technologies.

11. Did you receive funding from other sources for related work?

Home Depot gave materials and funding to the project. Unknown if there were other contributors.

12. Did you modify your research objectives to respond to the EPA solicitation? Would you do the research differently?

Nope, P3 open solicitation.

13. Do you have any further suggestions for the EPA?

Nope

P3 - Place-Based Green Building

Project: Place-Based Green Building: Integrating Local Environmental and Planning Analysis into Green Building Guidelines

Institution	Period	EPA ID	Grant
Auburn University Main Campus.	August 2007-March 2008	SU833566	$10,000

Principle Investigators: Retzlaff Rebecca

Interview

1. Could you tell us more about your project and why did you see a need for your project?

The project is about determining the best green technologies and approaches to use in specific areas. For example it makes sense for a building to be pedestrian friendly in urban areas. There is a need for this because there are flaws with the LEED rating system where developers will often take the cheap way out so they can get the points and not make functionality their top priority.

2. Could you tell us about the most interesting lessons and surprising results about your project?

This topic is far more complicated than originally thought to be. There is a lack of data for developing strong recommendations.

3. How does the regulatory climate affect your project?

There really weren't any regulation problems.

4. How does it tie in with green building and/or water infrastructure systems?

This is about building a green building that will maximize their environmental surroundings.

5. What were the technology needs and information gaps that were uncovered by your research result?
6. Did you consider commercialization for your research result? If so, how would you envision your product in the market and the challenges it would face? Who would be your primary customers?
7. Where has your research result been applied? What is the current scale of implementation of your technology? What are the barriers for expansion?

Cities, states and people who are not using LEED systems are potentially benefited from the research result.

8. Do you have current project ideas related to green building that need funding?

Still working on this topic of green location.

9. Where should future green building research focus, both in your area and more broadly?

Need more funding in this area

10. Did you receive funding from other sources for related work?

NOAA, they also sought USGBC funding but did not receive.

11. Did you modify your research objectives to respond to the EPA solicitation? Would you do the research differently?

No

12. Do you have any further suggestions for the EPA?

The EPA should fund more research in the social science area. Past grants were focusing on engineering research which makes it very hard for social research to receive funding. There needs to be more focus on policy and making buildings more locally adoptable.

SBIR - An Integrated Ecoroof Energy Analysis Model

Project: An Integrated Ecoroof Energy Analysis Model

Institution	Period	EPA ID	Grant
Quantec LLC.	August 2008 – August 2009	EPD06054	$69,856

Principle Investigators: Mr. Allen Lee (503) 228 2992 allen.lee@quantecllc.com

Interview

November 20, 2008 @ 12:00PM EST

1. Could you tell us more about your project and why did you see a need for your project?

Lee Allen has been involved in green building projects in the past, several dealing with reducing energy consumption. There is an effort to get new construction to be at least LEED certified. However, there is little empirical data and it has not been fully analyzed.

2. Could you tell us about the most interesting lessons and surprising results about your project?

The energy saving estimates was better than expected. There is noticeable heating savings.

3. How does the regulatory climate affect your project?

N/A

4. How does it tie in with green building and/or water infrastructure systems?

The project provides empirical data and understanding of the roof characteristics.

5. What were the technology needs and information gaps that were uncovered by your research result?

There needs to be more research into validation of the high energy savings proposed by having a green roof. There needs to be more research into finding the best materials and growth media to use. The stormwater quality is also another area that needs further testing and research.

6. Did you consider commercialization for your research result? If so, how would you envision your product in the market and the challenges it would face? Who would be your primary customers?

These results were used in a DOE Energy Plus Program, which runs simulations on green roofs

7. Where has your research result been applied? What is the current scale of implementation of your technology? What are the barriers for expansion?

The technology is used within the area but unknown how far it expanded. Needs more research to be implemented.

8. Do you have current project ideas related to green building that need funding?

This project did not get Phase II, which would have dealt more with evaluating the energy savings claims and implementation of the technology.

9. Where should future green building research focus, both in your area and more broadly?

Green roof lifespan, indoor air quality, what to do with existing buildings to make them more green, discover whether the systems in the building are performing correctly, ensure the building is performing as was designed, residential green roofs.

10. Did you receive funding from other sources for related work?

No

11. Did you modify your research objectives to respond to the EPA solicitation? Would you do the research differently?

Omitted

12. Do you have any further suggestions for the EPA?

EPA should provide more funding.

CNS - Smart growth planning to minimize degradation of water quality

Project: Mapping Regional Development for Smart Growth Planning to Minimize Degradation of Water Quality and Enhance Green Infrastructure

Institution	Period	EPA ID	Grant
Maine Department of Inland Fisheries and Wildlife		R833345	$249,919

Principle Investigators: Dr. Donald Katnik (207) 941 4455 donald.katnik@maine.gov
Dr. Steve Walker

Interview

November 20, 2008 @ 3:00PM EST

1. Could you tell us more about your project? Why did you see a need for your project?

This project is intended to guide the community and avoid urban development fragmentation. The result provides town planners with information about natural resources for new development. There is lack of large scale geographic data. The project also forecast future development from historical data.

2. Could you tell us about the most interesting lessons and surprising results about your project?

This is still in early stage. No surprising result has been identified yet.

3. How does the regulatory climate affect your project?

It's bureaucratic and slow to be able to apply and use federal money at state system level. It generally took 4 months for federal agency to approve contract.

4. How does it tie in with green building and/or water infrastructure systems?

The project aims at managing natural resource efficiently, stormwater runoff effectively. It also tries to preserve the environment and the quality of drinking water.

5. What were the technology needs and information gaps that were uncovered by your research result?

The geographic data is expansive regarding the total budget of the project.

6. Did you consider commercialization for your research result? If so, how would you envision your product in the market and the challenges it would face? Who would be your primary customers?

Other state can easily adopt and are recommended to use the technology and result.

7. Where has your research result been applied? What is the current scale of implementation of your technology? What are the barriers for expansion?

How to maximize collaboration and get everybody involved. Working with large amount of geographic imaginary data can take a lot of time without enough personnel.

8. Do you have current project ideas related to green building that need funding?

Focus on current project.

9. Where should future green building research focus, both in your area and more broadly?

Technology is often not an issue itself. It just has been used in the wrong place. Need research on hidden cost rather than just initial tax and cost to make it more apparent to home users and planners for decision-making.

10. Did you receive funding from other sources for related work?

No, without EPA funding the project wouldn't have happened

11. Did you modify your research objectives to respond to the EPA solicitation? Would you do the research differently?

Omitted

12. Do you have any further suggestions for the EPA?

None

CNS - Multi-Objective Decision Model for Urban Water Use

Project: Multi-Objective Decision Model for Urban Water Use: Planning for a Regional Water Reuse Ordinance

Institution	Period	EPA ID	Grant
Maine Department of Inland Fisheries and Wildlife		R833345	$249,919

Principle Investigators: Jeffery A. Wickenkamp

Interview

1. Could you tell us more about your project and why did you see a need for your project?

To provide technology transfer and knowledge to bring it further to the attention of the parties in the region.

2. Could you tell us about the most interesting lessons and surprising results about your project?

It is not confined in any individual or particular building. It is for retrofitting home neighborhood or city in a large scale working with a specialized treatment system. Some people think there is a cheaper way to do it. It is expensive because it involves piping and municipal systems. We are trying to identify the actual driver factor affecting the water reuse project.

3. How does the regulatory climate affect your project?

There isn't any regulation at the state level on industrial side. On irrigation side, we haven't looked much into. There is a regulatory gap for water discharge involving NPDES (National Pollution Discharge Elimination System) which are permit given to industrial and municipal discharge defining in Clean Water Act. State has also other system Slow Rate Land Application requires to put all the water into land and open space. The issue is there is nothing for water reuse. It would be helpful to have some guidelines.

4. How does it tie in with green building and/or water infrastructure systems?
5. What were the technology needs and information gaps that were uncovered by your research result?

There is problem with satellite reuse by tapping into sewage to treat it onsite instead of redistribution. Membrane technology is becoming cheaper which is potential.

6. Did you consider commercialization for your research result? If so, how would you envision your product in the market and the challenges it would face? Who would be your primary customers?
7. Where has your research result been applied? What is the current scale of implementation of your technology? What are the barriers for expansion?

8. Do you have current project ideas related to green building that need funding?

Other planning projects related to green building: water supply project on the region. We are try to estimate water demand and identify different possible water site. These projects are connected with each other.

9. Where should future green building research focus, both in your area and more broadly?
10. Did you receive funding from other sources for related work?
11. Did you modify your research objectives to respond to the EPA solicitation? Would you do the research differently?
12. Do you have any further suggestions for the EPA?

Principle Investigators: Paul Anderson

Interview

1. Could you tell us more about your project and why did you see a need for your project?

Illinois is running out of water.

2. Could you tell us about the most interesting lessons and surprising results about your project?

Water reuse is expensive to implement in urban area. There is resistance to change from the industries about water reuse because there are unknown risks associated with new methods even though it helps them saving money.

3. How does the regulatory climate affect your project?

The federal government has no water reuse regulation. They handle to the state to deal with while state of Illinois has little experience and hesitates to act because they don't know any hazardous problem related with water reuse.

4. How does it tie in with green building and/or water infrastructure systems?
5. What were the technology needs and information gaps that were uncovered by your research result?

Technology is not a problem: the technology exists; just the cost of implementing them is the problem.

6. Did you consider commercialization for your research result? If so, how would you envision your product in the market and the challenges it would face? Who would be your primary customers?
7. Where has your research result been applied? What is the current scale of implementation of your technology? What are the barriers for expansion?

Not yet to be applied. It could be applied to water reuse in the city of Chicago: Metropolitan Water Reclamation District of Greater Chicago (MWRDGC), Chicago Metropolitan Agency for Planning (CMAP). The research could be applied to other cities in the area around Great Lakes such as Indiana.

8. Do you have current project ideas related to green building that need funding?

There is a project on development on wastewater treatment using satellite membrane reactors for water reuse on-site instead of extending a secondary distribution system of pipelines for wastewater treatment plants

9. Where should future green building research focus, both in your area and more broadly?

Barrier of wastewater reuse: cost. There is no incentive to use water efficiently due to low cost of water. Problems related to water quality issues.

10. Did you receive funding from other sources for related work?

This is a collaboration project of 3 different agencies: Department of Economic Development in Illinois, Waste management research

11. Did you modify your research objectives to respond to the EPA solicitation? Would you do the research differently?

Fit in the solicitation. Just a little change about the place running out of water is not exactly in the Chicago.

12. Do you have any further suggestions for the EPA?

Because of the expensive cost of putting in a secondary distribution system, we are looking at some other values of. Hybrid system to treat wastewater and water also serves as a heat transfer medium.

Appendix F – EPA Offices Interviews

Office of Wetlands, Oceans and Watersheds

Interviewees	Ms. Abby Hall, Mr. Jamal Kadri
NCER attendants	Dr. Diana Bauer, Ms. April Richards
WPI attendants	Adam Brooks (Secretary), Manh-Hung Le (Chair), Brian Robie, Fidelis Wambui
Topic	Water infrastructure and stormwater management

<u>Interviewees Background</u>

Ms. Abby Hall	U.S. EPA, Office of Wetlands, Oceans and Watersheds
Mr. Jamal Kadri	U.S. EPA, Office of Wetlands, Oceans and Watersheds

Thursday, October 30, 2008 @ 15:00
EPA Ronald Reagan Building, 1424 EPA West

<u>Discussion</u>

Terms

CSO- Combined Sewer Overflow
MS4- Municipal Separate Storm Sewer System
IRE- Infiltration Reuse and Evapotransporation

Three scales: Watershed, Neighborhood, and Site

- *Watershed*: Most efficient to build in compact areas
- *Neighborhood*: Focus on street size, organization, and accessibility. USGBC is developing the program LEED-ND to promote green building of neighborhoods
- *Site:* Implemented technologies and efficiency of buildings

Examples of management systems and practices:

- General public disbelief about capabilities of newly developed systems to deal with water volume
- Common practices to manage stormwater are: green roof, rain garden, offline storage, and bedrock tunnel
- "Green into grey fabric" ~ Abby
- There are cases where it would be more cost effective to buy and/or construct water management systems for point sources than to upgrade the existing sewer system or CSO
- Realistic goal would not be to completely replace the sewer system but to implement management systems that control the smaller (under one inch) storms and have a back-up of the municipal sewer system

- Suggested interview with Steve Saari from Watershed department in the DDOE (District Department of the Environment) (steve.saari@dc.gov)
- Suggested talking to landscape architects as well.
- ASLA has data on effects of seasons on green roofs effectiveness in managing stormwater.
- Project DX? – Example: If a city building cannot incorporate stormwater management they can donate money to an area outside the city of equal value in terms of impact.
- Melissa Keeley has some data on stormwater management

Areas that need most attention

- Further research into methods for implementation of management systems
- Simple instructions and regulations need to be developed for the design and construction of various systems
- Lack of data to prove the effectiveness of green roof in urban areas. In many places, engineers and local government still rely on the traditional tunnel method rather than using new practices.
- Need to build social confidence in green water technologies.
- Already developed systems need to be simplified
- Incentives need to be given for implementation of management systems such as tax incentives and cost for the government to manage stormwater.
- Political regulation is one of the biggest barriers for implementing green building practices
- Stormwater practices often need constant maintenance and monitoring (In Chicago, the government implemented green alley practices however there was a lack of maintenance planning)
- There is no incentive for people to reuse and recycle water because it is cheap and readily available.

NCER Director - Dr. William Sanders

Interviewees	Dr. William Sanders
NCER attendants	Dr. Diana Bauer, Ms. April Richards
WPI attendants	Adam Brooks (Secretary), Manh-Hung Le (Chair), Brian Robie, Fidelis Wambui
Topic	Green Building Research Strategy

Interviewees Background

Dr. William Sanders U.S. EPA, Head of NCER

Tuesday, November 4, 2008 @ 11:30 AM

Discussion

We introduced our project to Dr. Sanders whereupon he gave us some of his ideas.

Dr. Sanders informed us there are approximately 80 green building projects sponsored by NCER

Dr. Sanders informed us of several green communities: Portland, Chicago

One of the biggest obstacles is getting people to do the "green" thing. Citizens need to be bribed into going green. People do not want to pay a premium for going green.

Dr. Sanders mentioned there are several P3 projects that deal with real time updating of water and energy use within a system.

We asked Dr. Sanders several relevant questions.

1. What do you think is the current gaps with green building technologies? Which areas are underdeveloped?

- Dr. Sanders mentioned that one of the biggest gaps with current green buildings is with developing metrics. We need to know what a constructed building is doing after construction. We need quantitative data.
- Commissioning of a building would ensure people are using the building correctly.
- Occupancy Surveys would ensure satisfaction of users

2. Our project is related to green building impacts to water infrastructure systems such as wastewater recycling and stormwater management. We are trying to identify the research gap to develop priorities for future research. Do you have any comments on this topic?

- Materials research is an area that needs further research.
- Water infrastructure is greatly influenced by location, making it a tricky subject.
- Need to know how much water we use
- Policies limit what can be implemented => waterless toilets

3. Green building research didn't receive a large amount of funding, approximately 3% of total EPA funding, relatively small compared to air pollution and other researches. Why there was such a deficiency in funding despite the potential benefits of green building?

- A green building strategy is only just now being developed.
- Projects sponsored in the past had no category to fit in.
- NCER wants to spend more money in the area of green buildings.
- Many of the projects sponsored by NCER results in policy creation rather than a consumer product. Policies would deal with regulating the existing contamination.
- Roughly 25% of SBIR projects result in a commercialized product.

4. Do you suggest any agencies or organizations other than the EPA and the NCER we should talk to?

- Inter Agency Workgroup => GSA
- Department of Energy
- USDA
- Department of Education
- Department of Defense
- Interview Source => Bob Thompson => has knowledge of indoor air quality and green building
- Some country in the EU has quantitative data on waste and water infrastructure.

U.S. EPA, Office of Pollution Prevention and Toxics
U.S. EPA, Green Building Workgroup

Interviewees	Ms. Alison Kinn, Mr. Ken Sandler
NCER attendants	Dr. Diana Bauer, Ms. April Richards
WPI attendants	Adam Brooks (Secretary), Manh-Hung Le (Chair), Brian Robie, Fidelis Wambui
Topic	Green building strategy and LEED rating system

Interviewees Background

Ms. Alison Kinn	U.S. EPA, Office of Pollution Prevention
Mr. Ken Sandler	U.S. EPA, Office of Research and Development Co-Chair of EPA Green Building Workgroup Member of USGBC Research Committee

---

Discussion

WPI intern team explained their project. Alison and Ken then gave an introduction into their offices.
Water foot printing => the water used to create a material needs to be accounted for.
There are 30 EPA building programs over the past 5 years.
ASTM, ASHRAE
USGBC has received some funding from the EPA. Energy Star program gave money. LEED ND was partly funded by green building at EPA
WPI intern team began asking questions in interview format.

1. Why are there more green buildings for the commercial sector than private or existing buildings.

- Easier market to affect
- Difficult to get existing homeowners to change;
- Big impacts come from commercial sector;
- Architects are biggest proponents of green.

2. What is current status of promoting green building in homes sector.

- Energy Star homes are 750,000 and increasing.
- Difficult to do at local level "not user friendly"; need to get people educated, understand the long term benefits that people usually don't care about
- Insurance companies interested in sustainability
- Builders often do not get the benefit of building the more expensive green buildings. Needs to be restructured

3. It seemed there is sufficient stormwater technology but lack of implementation, true or not?

- There is a lot of information that is bad, wrong, tricky for installation.
- Currently working on website with internal and external links for do it yourselfers

4. Downsides to LEED?

- There are other competing systems.
- There needs to be more of a minimal requirement to satisfy the EPA
- Need more prerequisites
- Points don't always make sense – Ex. Building a bike rack gets points no matter what the location of the building is.
- Need to reevaluate buildings to ensure they are working correctly.
- Region to region differences in LEED.
- Being addressed slowly. 2009 version speaks about regional chapters of LEED.
- Different points will carry more weight in different regions.
- Different LEED direction with LEED ND
- No, same direction more broad
- Star Community Index

5. USGBC have common metrics? Problems facing data and measure of performance?

- Need more focus on metrics and performance
- LEED has been criticized for giving new buildings plaques when there is no follow-up. Need to recertify.
- Some sources show LEED buildings perform little better than a regular building.

6. Places outside EPA and USGBC to look at?

NIST, DOE, European Union countries, Green Dragon

7. Green building at its tipping point?

- A lot of new interest.
- New administration.

8. What areas of green building need more research?

- Metrics, Life Cycle
- Technology exists, make it cheap and affordable
- Make it easier for homeowners to use and do
- Material Infrastructure => reuse, recycle, separate
- Indoor air => Ventilation systems, less toxic materials, certification

U.S. Drinking Water Research Program

Interviewees Dr. Audrey Levine

NCER attendants	Dr. Diana Bauer, Ms. April Richards
WPI attendants	Adam Brooks (Secretary), Manh-Hung Le (Chair), Brian Robie, Fidelis Wambui
Topic	Sustainable water infrastructure & drinking water program

---

<u>Interviewees Background</u>

Dr. Levine is an environmental engineer with extensive research experience in water quality, water treatment and distribution systems, treatment technologies, and water reuse. Prior to joining the EPA, she was a faculty member of the Department of Civil and Environmental Engineering at the University of South Florida in Tampa. She is a Diplomat of Environmental Engineering (DEE) and a registered professional engineer (P.E.). She has more than 20 years of broad-based, technical experience within academic, government, industry, and consulting settings. She has a doctorate in civil engineering from the University of California at Davis, and a master's degree in Public Health from Tulane University.

Terms:

- Hydraulic Cycle: - Flow of water in the environment.
- Water reuse, reclaimed/recycled water- not wastewater recycling

<u>Discussion:</u>

- In California
  - 10% of energy money is used for water transportation
  - Its an extreme example due to little availability of water sources and the higher energy efficiency in the state
- We should think of water not as separated with different classes such as recycled, grey/black water and stormwater, but rather have an integrated view and look at the whole system and how its transported and used. Also think of the energy used in the water system for transportation and such.
- How are water pipes sized? Why the infrastructure is built the way it is?
  - It was built in a way to provide enough water to put out a certain sized fire or a 2nd storey building for a certain amount of time.
  - Not built for other uses such as supporting population with drinking water
  - Nowadays it is also sized for perceived demand.
- Can you tell us more about the feasibility of on-site treatment and recycling of wastewater?
  - It requires less transportation so less energy which makes more sense in terms of efficiency.
  - Phoenix, Arizona is using recycled water for a Plant since there is little availability of water sources.

- We know that the regulations for using recycled wastewater as potable water are strict and even forbidden in some states. What level of regulation is necessary for the recycled water used in irrigation and flushing toilets?
    - There are no federal regulations for water recycling, the regulations are at state level so each state has different regulations
    - California and Florida recycle their water. Some of it is used in irrigating crops such as citrus crops.
    - There is also a lot of unplanned water reuse such as in the Mississippi River where different cities use the water for drinking and then put back treated water back into the river.
    - The USGS has an inventory of how water is used in agriculture and other industries which we should look up to determine water reuse statistics.
    - The EPA Water Reuse Guidelines contains all the state regulations for water use reuse which would be useful to our project.
- The school said the treated wastewater is drinkable but the regulations do not allow it to be consumed. What do you think about this issue regarding technology and ethics?
    - One of the issues is that the Safe Drinking Water Act does not regulate the pharmaceuticals contained in recycled water so part of the worry with state governments is the concern of the chemicals that could be harmful to human health.
- A problem we have identified is that the cost of water is too low, which creates little to no incentive for people to reduce or recycle their water. How does the EPA plan to change this perspective?
    - The EPA cannot regulate prices of water
    - Not much they can do other than educate people about the need to recycle water
- How much funding had been allocated for water recycling research? Do you think this amount of funding is sufficient?
    - The amount is not sufficient.
    - The EPA has to first and foremost deal with regulations meaning all their research has to deal with what regulations are around and future regulations. Since there are no regulations on water reuse, it is difficult to rally support and explain the need for the research.
- Where do you think future research should be focused regarding green building technologies and water infrastructure?

Recommendations & Areas in Need

- Where do you think future research should be focused regarding green building technologies and water infrastructure?
    - Think of water not as an afterthought when it comes to Green Building
    - Use good quality water for drinking water
    - But less quality water or recycled water for other uses such as irrigation, bathrooms, etc…
    - Perform mass balance analysis of water use to determine how much water is going into a system and coming out

    - Be more efficient when making water safe and be more energy aware with water use/transportation/recycling/treatment
- Come up with better ways to develop water infrastructure systems
    - Have a small pipeline for drinking/portable water since less water is used for this area
    - Another pipeline for irrigation/fires/cleaning and such
- We should have baseline regulations/standards for public health and water reuse/use
- Need to look at how all groups work together- water recycling, stormwater management, energy efficiency and others.
- Research different countries, states and organizations to find out water reuse information
- Japan, China, Namibia, Netherlands, **Australia (**have National Regulations on water reuse), Florida, California, Arizona, Water Reuse Foundation, Water Environment Federation(wef.org)

"It is best to keep water where it is and reuse it than to transport it and use energy."

WaterSense

Interviewees	Ms. Stephanie Tanner
NCER attendants	Dr. Diana Bauer
WPI attendants	Adam Brooks, Manh-Hung Le, Brian Robie, Fidelis Wambui
Topic	WaterSense program and water efficiency

<u>Interviewees Background</u>

Dr. Levine is an environmental engineer with extensive research experience in water quality, water treatment and distribution systems, treatment technologies, and water reuse. Prior to joining the EPA, she was a faculty member of the Department of Civil and Environmental Engineering at the University of South Florida in Tampa. She is a Diplomat of Environmental Engineering (DEE) and a registered professional engineer (P.E.). She has more than 20 years of broad-based, technical experience within academic, government, industry, and consulting settings. She has a doctorate in civil engineering from the University of California at Davis, and a master's degree in Public Health from Tulane University.

Interview

1. What is your most supported implemented device?

Currently only two devices exist. Bathroom faucets as well as low flow toilets. Other devices such as shower head and irrigations are in pilot stage.

2. What are the barriers to promoting your products?

Since WaterSense is voluntary, they have limited consumer outreach. They must rely on partners to promote their product as well as public servie announcements. WaterSense can not pay for announcements in advertising.

3. Is WaterSense looking into other water consuming devices, such as washing machines?

Currently they are working on 12 devices. Washing machines is not one of them because they are covered under the sister program EnergyStar.

4. What do you think about water reuse and rain harvesting in relation with WaterSense?

There is no need for these areas to be reviewed because they are efficient by their nature. They do not need a WaterSense label. There is no such thing as an inefficient rain barrel. WaterSense concentrates on the efficiency performance of water devices, it is currently has no plan to go on water reuse.

5. Are you planning to create product supporting water reuse?

Not inthe current future

6. What are the incentives for the residential market to push them to use less water?

There is no incentive really. WaterSense relies on advertisement by their supporters.

7. To what degree do you cooperate with the USGBC on LEED system?

This is an area that has been slowly developing. There is a need to analyze energy efficient devices that use water for cooling because often that water use is not only extremely high but also becomes contaminated. There are very few water efficiency points in the LEED rating system right now. The LEED currently has not adopted the rating system of WaterSense yet due to lack of products on the market. WaterSense is developing its own certificate for water efficiency.

8. You have some partners with contractors and water appliances manufacturers such as Timothy Maloody and Kohler. What is the percentage of supporters in construction industry with WaterSense products?

There is no way to get exact numbers. The numbers WaterSense receives come from the manufactures on how many devices they ship to market. After only one year WaterSense products had captured approximately 2% of the market.

9. It seems water availability is becoming or has become a prominent issue throughout several areas of the US. Does WaterSense have any plans or ideas for these areas?

Seatle, Texas, and California are areas that need more effort.

10. What are the areas regarding green building technology (especially in water infrastructure) that need more research?

There is no statistical data detailing the impacts of saving large amounts of water from a particular building on the existing water infrastructure. There is research needed in “Pre Rinse Spray Valves” which are typically found in restaurant kitchens to pre wash the dishes.

Appendix G - Regulatory for the NCER

Clean Air Act--Section 103.

Section 103 of the Clean Air Act authorizes the EPA to make grants to institutions for research, investigations, experiments, demonstrations, surveys and studies relating to the causes, effects (including health and welfare effects), extent, prevention and control of air pollution.

Federal Insecticide, Fungicide and Rodenticide Act--Section 20.

Section 20 of the Federal Insecticide, Fungicide and Rodenticide Act authorizes the EPA to make grants for pesticide-related research, development, monitoring, public education, training, demonstrations, and studies.

Solid Waste Disposal Act--Section 8001.

Section 8001 of the Solid Waste Disposal Act authorizes the EPA to make grants for research, investigations, experiments, training, demonstrations, surveys, public education programs and studies relating to: (1) adverse health and welfare effects from solid waste; (2) solid waste management programs; (3) resource recovery and conservation, and hazardous waste management systems; (4) production of usable forms of recovered resources; (5) waste reduction; (6) improved solid waste collection and disposal methods; (7) identification of solid waste components; (8) small scale and low technology solid waste management systems; (9) methods to improve performance of recovered solid waste; (10) improvements in land disposal practices; (11) methods for sound disposal of resources, including sludge and coal slurry; (12) methods of hazardous waste management; and (13) air quality impacts from the burning of solid waste.

Clean Water Act--Section 104.

Section 104 of the Clean Water Act authorizes the EPA to make grants to institutions for research, investigations, experiments, training, demonstrations, surveys and studies relating to the causes, effects, extent, prevention, reduction, and elimination of water pollution.

Clean Water Act--Section 104 (freshwater ecosystems)

Section 104 of the Clean Water Act authorizes the EPA to make grants to colleges and universities to conduct basic research into the structure and function of freshwater aquatic ecosystems and to improve understanding of the ecological characteristics necessary to the maintenance of the chemical, physical, and biological integrity of these systems.

Safe Drinking Water Act--Section 1442.

Section 1442 of the Safe Drinking Water Act authorizes the EPA to make grants for research, training, studies, and demonstrations relating to the causes, diagnosis, treatment, control, and prevention of physical and mental diseases and other impairments of man resulting directly or indirectly from contaminants in water, or to the provision of a dependably safe supply of drinking water, including (A) improved methods: (i) to identify and measure the existence of contaminants in drinking water (including methods which may be used by State and local health and water officials), and (ii) to identify the source of such contaminants; (B) improved methods to identify and measure the health effects of contaminants in drinking water; (C) new methods of treating raw water to prepare it for drinking, so as to improve the efficiency of water treatment and to remove contaminants from water; (D) improved methods for providing a dependably safe supply of drinking water, including improvements in water purification and distribution, and methods of assessing the health related hazards of drinking water; and (E) improved methods of protecting underground water sources of public water systems from contamination.

Toxic Substance Control Act--Section 10.

Section 10 of the Toxic Substance Control Act authorizes the EPA to make grants for research, development, monitoring, public education, training, demonstrations and studies directed toward the development of the fundamental scientific basis of screening and monitoring techniques used to detect toxic chemical substances and quantify the effects of toxic chemical substances and mixtures in the environment.