The University of Toledo

Research to Practice Phase 2 Report

Development of Tools for Evaluation of Rainwater Harvesting Systems

Primary Contact:

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Advisory Team:

Defne Apul, Cyndee Gruden, Michael Green, Ann Krause

Student Team:

Robert Phillips, Jay Devkota, Chirjiv Anand, Thelma Winter Rodriguez

COVER SHEET

Faculty and Staff Bios:

The University of Toledo Phase II team is led by Dr Defne Apul. She specializes in sustainable designs and concepts on water and sanitation systems of buildings and cities. Her knowledge and contagious passion for environment engineering has led to an increased interest base at the University of Toledo and surrounding community. As an Associate Professor, Dr. Apul has developed and implemented a new course on Sustainability Engineering and presented LEED related research opportunities for students of different levels. Dr. Apul is actively engaged in community conferences related to sustainability as well as other green topics. Through these and many other initiatives, Dr. Apul has helped led the way in our community, pushing for ethical behavior and environmental consciousness. Throughout the course of this project she has provided team management and direction while providing key resources for our research team to investigate and strengthen the body of our work. She has been paramount in providing opportunities through her many connections, opportunities such as conference dates and new material.

Dr. Cyndee Gruden is an expert in environmental engineering. Her experience in the field has been invaluable to the team composition. Dr. Gruden was heavily involved in Phase I research and was helpful in guiding our work in Phase II. She helped steer team efforts knowing the weaknesses and strengths of Phase I knowledge and team skills.

Micheal Green is the Energy Management Director at the University of Toledo. His influence at the University level has helped our outreach program. His knowledge of LEED through his past projects has posed as an excellent resource, as he has the practical knowledge and has encountered the problems in implementation through experience. This has helped our team anticipate problems and contemplate solutions before the fact.

Dr. Ann Krause specializes in systems analysis and is with the College of Innovative learning. Her background has allowed us to take a cradle-to-grave analysis and understand the implications from various approaches to our research topics including the social implications of our work. Through her involvement, our research has been able to spread beyond the typical building community and gain alternate routes of exposure.

Student Team Bios:

Robert Phillips has led the student team and devoted most of the time in this project. He is an undergraduate student at University of Toledo pursuing Bachelors of Science in Civil Engineering. As part of his USGBC Phase II research, he is currently also participating in the University of Toledo Undergraduate Research Program. This program selects students on a competitive basis and develops students' research skills. Robert contributed to the team's efforts through developing, debugging, revising all of the tools produced from this project.

Jay Devkota is a new doctoral student at University of Toledo with a research focus on mathematical modeling of rainwater harvesting systems at building and watershed scales. Jay joined University of Toledo and our team in the middle of the project and helped with our YouTube, Webpage, and Prezi outreach efforts.

Chirjiv Anand is a doctoral student at the University of Toledo. Her current research is focused on the environmental and economic evaluation of decentralized sanitation systems. Her master's work focused on transportation sustainability. Chirjiv's extensive experience on life cycle assessment contributed to our team in building the Excel model and in resolving some water infrastructure questions we had.

Thelma Winter Rodriguez has an undergraduate degree in environmental sciences and is currently pursuing Masters in Environmental Engineering with a research focus on Energy Star and the relation with waste water treatment plants and their energy efficiency at University of Toledo. Thelma is also a representative of the local Northwest Ohio Chapter of USGBC. With her position Thelma is able to keep our team up to date on the latest actions by USGBC and their practices. She also helped in our understanding of the energy implications of using municipally supplied potable water.

Statement of Purpose:

The main purpose of our team is to inform and educate through our research findings related to building water and sanitation systems and more specifically the role of rainwater harvesting within buildings. The process was targeted to bring a positive change in the use of classic water and sanitation systems. Over the past decade sustainability problems have become more prevalent than ever. Publications on climate change, news coverage on energy and global warming issues, and intensifying seasons all suggest one goal, change. As our research team educates themselves and each other, we wish to convey that knowledge and message to the public as well as regulatory agencies in order to gain exposure and protect our future in both an economic and environmental efficient manner. With this context in mind, our work has specifically focused on water and sanitation in buildings, their economic implications, and their connection to energy and climate change. Our team developed a tool to educate the students, public and the construction community on this topic.

Executive Summary:

The Research to Practice Phase II Research Report submitted by our team outlines the steps that have been taken towards our purpose with respect to the USGBC program. Our Phase II naturally built off of what we had learned through our Phase I results. As our research focused on the viability of rainwater harvesting systems we discovered that the gap between research practices and implementation primarily consisted of an incomplete means of analysis from a life cycle assessment approach. In order to fill this gap, our Phase II team set out to create a tool that will provide a holistic analysis of rainwater harvesting from construction through the entire useful life of the technology. Towards this end the Economic and Environmental Analysis of Sanitation Technologies (EEAST) model was created. With user inputs the EEAST model calculates and displays an array of results, from traditional financial standings, to energy and carbon dioxide equivalent emission savings. To make the model and our work more appealing and user friendly to potential users, complimentary tools were developed such as a Prezi presentation, Youtube tutorials, a website, and a manual. To increase our outreach we have already submitted abstracts to two conferences and plan on presenting our results in several more, hopefully Greenbuild 2012 being one of them. We

have also published a news article about our work in the Summer 2012 Newsletter of Northwest Ohio Chapter of USGBC.

References:

For further details on our team, individual members, publications, and successes please visit the following online resources:

EEAST webpage: http://eeast.wikispaces.com/

Sustainability Engineering Lab: http://defneapul.wikispaces.com/

Existing UT LEED buildings: http://www.utoledo.edu/facilities/energymgmt/LEEDSbldgs.html

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1. Introduction

In Phase I of the Research to Practice Program, our team investigated several different buildings on the main campus of University of Toledo and analyzed the viability of rainwater harvesting systems. Through this investigation the team calculated payback periods form implementing these systems while considering unique conditions within these paybacks. Nontraditional paybacks were interpreted and quantified, such as carbon emissions and impacts of additional student recruitment due to presence of aesthetic rainwater harvesting systems. The Phase I work showed that initial costs of rainwater harvesting systems may be high, but there are innovative means of attaining the required benefits. Creative end uses for the captured rainfall such as living walls and green walks were considered in order to fully utilize the systems. Also, alternative means of capturing and storing the rainfall were considered. Typically a metal cistern is used, technologies such as rainwater bladders were designed and specified in order to meet or exceed the useful capacity of a traditional cistern.

Phase I team identified areas of improvement for the green construction community: new tools are necessary for evaluation of non-traditional water and sanitation sytems in building.

By the end of Phase I, our team identified some areas of practical improvement within the green construction community. Our research investigations emphasized the need for new tools and analysis methods in order to maximize the sustainability of the construction and infrastructure industry. As green building technologies evolve, means of design analysis must evolve with it. Our team's Phase I research discovered that this was not the case when perceiving energy and green house gas emissions. Our research found that there were only tools for analyzing cost payoffs for some of the standard green technologies. Tools that go beyond economic analysis and couple energy and emissions are also necessary for quantifying the benefits or shortcomings of perceived sustainable systems. However, such tools were missing for many technologies and most certainly for rainwater harvesting systems. In light of this, our Phase II work focused on the development of a Microsoft Excel model with associated outreach and educational modules that can be used as decision-making criteria in sustainable construction related to Water Efficiency and Sustainable Sites credits of the LEED rating system.

Through this program, our focus weighed heavily on water and sanitation improvements. Our team collectively observed this portion of modern infrastructure as a weakness, which drastically needs improvements. Currently American water infrastructure loses 20% of the potable water conveyed from water supply plants through leakages in the system. The generalized public opinion on this is that water is an abundant resource so it is not of immediate concern. Water is one of our planet's most abundant resources, but when you transfer these resources into a cost and energy value the statistic becomes more of concern. An average of 3% of the entire U.S. energy demand is utilized through the treatment and conveyance of water. Again, 3% seems like a small number, however, this 3% equates to a 4 billion dollar sum. 4 billion dollars is spent annually, 20% of 4 billion dollars is 160 million. Approximately 160 million dollars worth of water is lost through our current infrastructure and associated inadequacies due to leaks and other inefficiencies.

Water is a precious resource and we are wasting water, energy, and dollars due to leakage in municipally supplied water.

The model which we developed in order to combat the centrally provided water infrastructure setbacks is called EEAST, where EEAST is an abbreviation of Economic and Environmental Analysis of Sanitation Technologies (EEAST). EEAST was first developed by University of Toledo alumni, Hannah Schlachter. The focus of the Phase II team was on further improving the calculations and user interface of EEAST including adding calculations for it to automatically calculate possible LEED credits that can be earned using the modeled technologies. In addition, the Phase II team worked on making EEAST increasingly user friendly while developing educational tools for the construction community.

EEAST provides an alternative to the centralized sanitation techniques considering the cost, energy, and global warming implications.

EEAST is a Microsoft Excel model that analyzes cost, energy, and global warming implications of alternative, decentralized sanitation technologies and their use throughout the life cycle of the building in which the technologies are to be coupled with. Systems modeled include using municipal water versus harvested rainwater in the building for toilet flushing and irrigation water end uses. Composting toilets, a waterless sanitation technology, can also be analyzed by EEAST. EEAST results are presented in terms of cost, energy, and emission payback periods. In addition, the Net Present Value (NPV) of the analyzed systems is calculated. These outputs can then be used by the construction community to determine which water and sanitation system may be the most sustainable solution for the specific building analyzed.

1.1 Intent

For Phase II, our team's research aim was to develop educational tools that can be utilized by a wide audience. Our research focused on tool development because we believe tools can have a greater impact on and empower the green construction community compared to a singular analysis of an existing LEED building. Once fully developed, our tool, the EEAST model, will have a range of site applications, which again goes beyond a single analysis.

A computer model, a YouTube video, a Prezi presentation, and a website were developed to educate the community.

The EEAST model has the capacity to provide informed decision making criteria for a wide community including designers, researchers, contractors, engineers, and the general public. It provides sustainability metrics of cost, energy and greenhouse gas emissions of different water and sanitation system designs and technologies. EEAST model displays the benefits of decentralized sanitation systems (e.g. using harvested rainwater instead of municipally supplied water), pre-construction, in order for the design team to have upfront knowledge on payback periods and make informed decisions on the benefits of implementation. Models are excellent ways to learn about different concepts. Therefore, running the model and analyzing the results will also have educational values for students and professionals.

To increase the educational and outreach value of our work, our team also developed a YouTube video, a website, a manual, and a Prezi presentation. We aimed to transform the student and construction community with these tools so they can actively and critically evaluate building technologies. Beyond our team's optimism of green technologies, such as the rainwater harvesting systems, composting toilets, and low flush toilets can also be analyzed by EEAST model. It is our intent to educate as well as motivate the general public to push for a sustainable future. Through the emphasis of decentralized technologies, we aim to continually produce tools and outreach ventures that will display the benefits and ultimate *need* for research to be adopted into practice.

1.2 Filling a Gap

Although it is the research team's consensus and general belief that sustainable designs should be incorporated in all new construction, due diligence must still be taken into account throughout the implementation process of these designs. Labeling a technology sustainable does not mean that it is suitable or sustainable in all cases. Sustainable technology, although progressive, may not always be a viable alternative and actually cost more for a building owner who will not realize the benefits of a system within the building's useful life. Similarly, even if a technology has been labeled as sustainable, it may cause greater energy and emissions in its life time compared to more traditional alternatives. The Phase II research on Rainwater Harvesting Systems has been completed in such a fashion to add clarity to such issues by providing accurate and reliable data on payback periods, life cycle cost, and environmental impacts.

Sustainable technology though progressive, may not be suitable in all cases.

EEAST will provide users with valuable information on the benefits of alternative, decentralized, sanitation technologies. With analyses providing details on the payback periods of the considered technologies and the "gap" that existed between a sustainable concept and final implementation will be filled with reliable data pertaining to the five modeled scenarios.

1.3 Impact

Why should public care of rainwater harvesting?

Through our outreach in Phase II, our team realized how ignorant the public is regarding rainwater-harvesting systems. When some individuals were asked on their opinions of rainwater harvesting systems responses were of the quality, "yeah, I have a rain gauge on my back porch: collects a few inches and tells me how much rain fell, but I'd rather just watch the news". These types of responses drew some red flags for our team. We realized that having a choice group of students and staff would not be enough, and traditional means of research, with articles and associated literature being published in scholarly journals, would not cut it. The public does not read these journals, therefore it would not be logical in thinking that information and research in these types of publications would gain wide scale appreciation. Therefore, we focused on developing the necessary technical knowledge base by writing a technical report of our work but we also focused on developing more public-friendly tools such as the Prezi presentation, the YouTube video and a website. In addition, we developed a diverse team inclusive of members in different positions, which helped us improve the impact of our research.

1.3.1 Local Impact

As a benefit of our interdisciplinary team we are optimistically aiming for our work to lead to the construction of a rainwater harvesting system coupled with an existing University of Toledo building. This tangible result will provide the community with more than just research and numbers, but a physical representation of the practice. With this as an end result of our work, public signage and other creative marketing tools will be utilized to increase the knowledge and interest of rainwater harvesting systems. Having the Energy Manager of the University, Michael Green, as a member of our team helped us toward this goal. While there are no definite plans yet, Mr. Green began looking for opportunities for our campus to harvest and use rainwater. Having a real project designed and implemented will take our project full swing. We will have truly hit the mark of Research to Practice and be able to outline benefits and shortcomings of a rainwater harvesting system with increased accuracy.

In working with the College of Innovative Learning our team has been able to extend interest to more than just the "building" community. Utilizing this network and the unique location of the University of Toledo relative to local neighborhoods, several opportunities present themselves in terms of educational impact. One such opportunity involves University art students.

Our team member, Ann Krause from College of Innovative learning suggested that art students could possibly customize rain barrels. Since funds for implementing a new rainwater harvesting system on campus do not exist, Mr. Green suggested that selling these customized rain barrels to surrounding homeowners may help raise the funds for purchasing a large scale cistern to be used on campus.

1.3.2 Regional Impact.

In order to enhance our impact, our team has submitted two abstracts to two regional conferences where our work will be presented. The first conference is organized by American Water Works Association (AWWA) and the meeting will be held in Dayton in September 2012 from 18^{th}-21^{st}. The second conference is the Undergraduate Research Symposium that will be held in Columbus, Ohio. In addition, we recently reached out to the Northwest Ohio construction professionals by publishing our Phase II work in the local USGBC chapter newsletter. We anticipate gaining even more exposure in Northwest Ohio by participating in the Northwest Ohio Sustainable U conference which is being held at University of Toledo this year.

1.3.3 National Impact

With the development of the model and its outreach tools such as the website, the YouTube and the Prezi presentation, we are aiming to have a national impact on the construction community. We have also made contacts with the American Rainwater Catchment Systems Association (ARCSA) who showed interest in sharing our products with their members. They are also interested in linking from their website to the EEAST website that we have developed. Finally, our team began working with the American Society of Civil Engineers (ASCE) Rainwater Harvesting System Task Committee who is currently preparing a document on the status of rainwater harvesting systems. Our work and results will be shared with them for possible use in their report.

2. Forming the Team and Team Composition

Forming the advisory team to students was fairly easy since several professionals on campus are already working on green construction issues and were happy to come together to work with students on rainwater harvesting. However, forming the student team was no easy task. The project began with one civil engineering undergraduate student who had to drop the project due to personal reasons. Then, a second undergraduate student, Robert Phillips started working on the project on a volunteer basis. Robert's enthusiasm and hard work led to him receiving a competitive undergraduate student research stipend award, which provided additional motivation to carry on and finish the work. With the help of our advisory team members, we searched for non-engineering students to join our team; however, we were not able to find a student who could commit a meaningful number of hours. Most students seek either credit or payment for their time. In addition, we found that students outside of the realm of what is considered typical building design/engineering are hard to recruit because at first glance the project does not specifically work with their degree plan. Therefore, recruiting a major not directly involved in green construction requires finding someone who has special interest in this topic. We were not able to identify such a person given the short period of time.

Robert was later joined by two other students that worked on the project primarily due to their own personal interest in this topic. The Phase II team composition is shown in Table 1. We have a diverse advisory team with two members from the civil engineering department, one member from College of Innovative Learning and one member from facilities and construction department, energy management unit. Among the student team, we have diversity in the levels of experience with one undergraduate student, one Masters student, and one PhD student. We also have ethnic diversity in the student team with white, Hispanic, and Asian ethnicities. In addition, one of our student members is an international student.

Table 1: The University of Toledo Phase II Research to Practice Team

Name	**Affiliation**	**Project role**	**Expertise**	**Actual Input to Project**
Defne Apul, Ph.D., P.E.	Associate Professor of Civil Engineering	Project contact and primary supervisor	Integrated water management, energy efficiency, life cycle assessment	Supervised all aspects of the project from beginning to end.
Cyndee Gruden, Ph.D., P.E.	Associate Professor of Civil Engineering	Advisory team member	Student advising, engineering design	Helped with student recruitment, provided suggestions for project improvement
Ann Krause, Ph.D.	College of Innovative Learning	Advisory team member	Innovative educational approaches, systems analysis	Helped with student recruitment, provided suggestions for community outreach
Michael Green	Energy Manager of the University (Facilities and Construction Department)	Advisory team member	Energy management and facilities operations	Advised regarding implementation of rainwater harvesting on campus.
Robert Phillips	Civil Engineering Undergraduate Student	Student team leader	Technical writing skills, project management, electronic media	Led the student team. Revised and improved EEAST. Wrote USGBC article. Worked on all deliverables of Phase II project.
Thelma Winter Rodriguez	Environmental Engineering Masters Student and Board Member of Northwest Ohio Chapter of USGBC	Student team member	Water and energy systems, LEED	Connected our team and our work with the local USGBC chapter by updating us on the chapter activities and updating the chapter on our activities during chapter meetings. Provided expertise on energy implications of our local water and wastewater treatment plants.
Jay Devkota	Environmental Engineering PhD Student	Student team member	Water Resources, electronic media	Worked on Prezi presentation, Youtube, and report.

3. Project Management

Throughout Phase I and Phase II our research team has been extremely well orchestrated. Our advisor team members, with their invaluable experience, have driven our team toward success. Our team consists of bright individuals, but without the managerial component provided by the advisors we would have never been able to complete the necessary tasks within a timely fashion, nor would the quality of work been as good. The following subsections outline strategies that were utilized in keeping our team on schedule and meeting our deadlines.

3.1 Define a Schedule

In order to stay on task our team established deadlines and interim checkpoints with respective goals. Originally a broad outline was constructed in order to conceptualize how the tasks at hand could be accomplished given the timeline of the project. A rough outline of expected hours and deliverables was constructed as a means to clearly identify the participation required from each team member.

As the broad schedule was completed and tasks were distributed amongst the group, smaller, individual schedules were compiled as a means for each member to continually stay on track and log their progress toward the teams established end goals. Progressing through our work in this manner was very effective. With all tasks presented each team member knew if they were going to be able to meet their deadlines, and if they weren't the slack was picked up by another member who was willing to help out to ensure the overall progress of the group.

3.2 Clear Methods of Communication

As a team we were able to effectively communicate progress and questions through the continued update of our individual schedules through cloud servers, email exchanges, and regular weekly meetings. Using these means of communication allowed for our team to receive prompt feedback to any questions that arose. The utilization of Dropbox and a shared folder allowed us to access, update, and comment on work to make sure that it was of the quality expected by the team. Weekly meetings ended with a list of tasks each member needed to complete before the next meeting. These tasks were discussed several times to make sure everyone was on track with the project work.

4. Our Stories

Through our team's ever pursuant sustainable ideals, a rainwater catchment tank was installed on an existing University of Toledo building. This is how our Phase I team got started. University of Toledo installed that tank, without considering end uses of the captured water, or considering appropriate sizing of the tank. The tank is very small, but the capacity that it does have was underutilized until the Phase I team analyzed different alternatives for the end uses of the system. These designs led to the implementation of green walks which provided run off control and improved the aesthetics of the building. Meeting these preliminary goals increased the University's interest in utilizing some of these more progressive approaches by utilizing sustainable technologies and practices.

University of Toledo students, for several years, have experienced the shortcomings of the current stormwater management design on main campus. One of the main drives, Stadium Drive, traverses through the heart of campus, adjacent to the football stadium, Glass Bowl Stadium, and has a valley low point. Student's who walk to classes often refer to the valley as "heaven and hell", where walking down one side is "heaven" and walking up the incline is "hell". During heavy rain events this main artery is shut down due to the abundance of stormwater build up. Our research has been advertised beyond an alternative source of potable water, but also as a stormwater management technology as it captures stormwater for a beneficial use. The students who have become aware of this initiative expressed great enthusiasm when hearing about the potential solution for the Stadium Drive stormwater problem. Our team believes that if we can be involved in engineering controls for problems that students realize and experience firsthand, our work will be far more appreciated, and gain greater exposure as the benefits can be seen beyond just statistics and numbers, but effect actual lives.

Is The University of Toledo an ideal place for RWH systems?

Beyond campus life, our local communities have recognized our efforts toward creating a sustainable community and infrastructure. The Northwest Ohio Chapter of USGBC invited our research team to help provide input and select the regional priority credits for LEED 2012. Our team's local recognition, as professionals in the field, has been one of our greatest assets. This collaboration between the regional chapter and University of Toledo research team has allowed us to provide input on the LEED 2012 regional credits. Our local community is widely aware of the stormwater problems facing our region. With our support, our local chapter voted to include Sustainable Sites credits as our regional credits for the Northwest Ohio Chapter. The more that our team is aware of current LEED updates and modifications the more we can tailor our research to be consistent with these goals. By the same token as we develop new tools and innovations we have a strong means of communication with a local green construction community, which provides an excellent means of exposure and means of feedback. Our local chapter has invited us to present our work to all their stakeholders.

Signs of climate change have been altering people's way of life. Northwest Ohio is no stranger to snow, living in the Great Lakes region we know what is to come in the winter months. However, this year, if you blinked the snow was gone. Those who depend on consistent weather patterns have suffered due to these changes. The onset of early spring temperatures had several economic effects on the community at large. Businesses such as ski resorts struggled as they have the technology to fill their mountains with fabricated snow, but do not have the power to change the appeal of their market base that seek natural snow and without it view the skiing/snowboarding as mediocre at best. With the strange weather sequence, we experienced pockets of typical winter weather after spring conditions had already hit. Local nurseries were hit hard with this as they had to take extra measures and precautions to protect their plants that had bloomed early due to the spring weather and became endangered when the winter weather finally came. These strenuous precautions ultimately cost money and the stock that did die off had to be replaced. Beyond this form of hardship we have experience strange rain conditions. Approaching drought conditions, crops are strained until the rain finally does fall. One of Ohio's, not just Northwest, main products is crops. With these types of conditions, attaining the yield that has become expected is increasingly difficult for farmers and as the source of market goods is strained, the price spike can be seen by the consumer.

In recent years we are facing higher amount of rainfall compared to the previous years and this trend is expected to increase in the future. The stream flow obtained for the Ottawa River near University of Toledo showed that May of 2011 has the maximum amount of precipitation as compared to the recent years. Stream flow data were obtained from USGS website.

5. Defining Focus

The project initially started with a general focus on rainwater harvesting systems. We considered analyzing different buildings for their water efficiency and sustainable sites credits. However, we later on decided to focus our efforts in tool building since tools provide an excellent way to learn about issues, concepts, and solutions. Knowing the EEAST tool was already somewhat developed at the University of Toledo, we decided to further develop this tool and make it available to the student and professional communities. Creating schedules for each team member, meeting weekly to review and revise our schedule and goals helped focus our efforts towards the ultimate products we are submitting for our Phase II work.

Though the project initially started on rainwater harvesting systems, it ended up changing direction towards tool development for water use in buildings.

6. Work Accomplished/Educational Products

Our team's greatest accomplishment has been recognition, not the recognition of our team or department, but the results of our work. Through our teams' research a large audience has come to benefit. Through casual conversations, to displayed results, our work has grown in recognition as others have gained interest in the topics of our research. Divulging the rewards of sustainable technologies such as the ones focused upon by our team, is not only the goal of this project, but is of paramount concern to our team.

6.1 Environmental and Economic Analysis of Sanitation Technologies (EEAST) Model

> *EEAST considers energy, water, and money in the preconstruction phase for 75 years of future life of a building*

The EEAST model is our research teams' main deliverable in Phase II of this project. As society begins to realize, but not necessarily embrace, that money is not the most important aspect of current designs and plans for the future, new methods of project analysis must be considered. The design of the model is intended to suit these new practices and go beyond simple financial analyses. Using life cycle assessment tools and strategies, CO_2 equivalent emissions are considered in pre-construction phases throughout the 75-year useful life of the building that is considered in the analysis. These data are compiled and presented in a manner consistent with typical payback periods seen in financial analyses. Since EEAST was already somewhat developed by former University of Toledo alumni, our efforts focused not on creating a brand new model but improving an existing framework. The specific developments added to EEAST in phase II include:

1. Improvement of user interface of EEAST
2. Debugging and changing of some codes within EEAST
3. Analysis of four different types of buildings using EEAST
4. Addition of calculations and user interface for LEED points that can be achieved using systems modeled in EEAST
5. Creation of an EEAST user manual
6. Creation of a set of YouTube video tutorials
7. Creation of a Prezi presentation outlining the benefits of rainwater harvesting and decentralized alternatives
8. Creation of a website specific to EEAST for feedback forums and comments as well as a means to automatically sync updates from our team

Details on how EEAST works including items 1-4 in the list above are included in the manual we created. Therefore, we do not include a detailed discussion of EEAST here. All tools that we developed are available on the EEAST website (www.eeast.wikispaces.com)

6.2 EEAST Manual

In order to create an educational tool that can be applicable to a wide range of audiences a manual for the EEAST model was created (Appendix B). The manual begins with an introduction to the model including some logistical questions such as its cost (it is free) and how it can be accessed.

Then, the manual discusses the input parameters and end results displayed by the model. The equations used in the model are displayed in order for the user to observe how the results were obtained. Specifics for the varying sections within EEAST are described as an outline so the user can distinguish between the interpretations of the individual input parameters.

Finally, the manual has an example simulation, which acts as a roadmap for the user to follow should they need further assistance in navigating the model. As EEAST has the capacity to model different building types, we have plans to further improve the manual to include simulations for each building specification as to avoid any confusion in user error. As the simulations walk through the model from start to finish, the interpretation of the end results is discussed and observations are made.

6.3 YouTube Video Simulation

As an additional resource and in order to further explain the EEAST model while providing a more intriguing visual, a stream of YouTube videos was created to outline the key points within the EEAST manual. The videos are broken up into sections as an effort to provide quick lookup tools. For instance if a user were to be having trouble with the financial inputs and interpretations within EEAST, they would seek out the second video with the YouTube sequence. YouTube videos can be accessed from EEAST website (www.eeast.wikispaces.com) that we developed as part of Phase II project.

The University of Toledo has recognition within organizations such as Ohio Section American Water Works Association, The American Rainwater Catchment System Association and others. Now it is time to explore our research findings globally.

6.4 Prezi Presentation

A Prezi presentation was created as an educational tool outlining major benefits of rainwater harvesting systems, composting toilets, and decentralized water supply technologies for toilet flushing and irrigation as a whole. This presentation has posed as one of our greatest marketing assets. It is easily accessible through our team's webpage and open for anyone to observe. The presentation provides great background knowledge on the science behind the technologies which our team has chosen to research. With this outlined in the style of Prezi, it is more captivating than a typical PowerPoint or similar lecture based presentations. The results of this approach have led to an apparent increase in retention of the presented material due to increased interest and audience appeal.

6.5 Webpage

In order for our team and research results to be accessible at user convenience we created a webpage with links to our deliverables as well as many other related resources. Our webpage has descriptions of our team members, including research interests and educational level/goals.

As a more specific resource for our Phase II work, our team created a webpage titled EEAST. This webpage serves as a means for direct feedback from users and as an information hotline for our team to our audience. Within this webpage all of our research deliverables can be accessed. With EEAST and general research updates tracked on the page our progress can be seen and hopefully interests sparked.

6.6 Outreach

Through the University of Toledo's involvement with surrounding communities and recognition by other organizations, we have been able to extend the reach of our results through multifaceted programs and outlets. Our team has submitted an abstract (Appendix C) to participate in The Ohio Section American Water Works Association (AWWA) 2012 Student Paper Competition. Through this submission we are to compete with other universities for a spot in presenting our research results and developed tools for water resource management as a sustainable practice. Participating in this competition allows our team to be recognized by water resource professionals whose insight, critiques and background knowledge is invaluable.

Our team has been in communication with The American Rainwater Catchment Systems Association (ARCSA) as another channel of exposure for the EEAST model and our associated sustainable ideas. They have shown interest in posting EEAST on their webpage as well as heavy enthusiasm towards a model with such strong outputs. This is one of our more optimistic passages of exposure as ARCSA is a well known and respected association, recognition through them will attract a high level audience to our research and bring about new ideas, improvements, and utilization of our tools towards the implementation of sustainable design principles.

Our team is primarily composed of civil, environmental, engineering students ranging in level from undergraduate to the doctorate level. It is the belief of our team that all branches of civil engineering need to be aware of sustainable alternatives to traditional construction and standard of living requirements. In order to expose and highlight these ideals we are presenting our research as an "in-house presentation", not only to educate, but to receive feedback from our peers. The more we present our material, the more questions that will arise and as a corollary to that, an increasing number of answers and facts can be sought out. Our team is always looking to improve upon our work.

We are outreaching to a wide community by presenting our work in many conferences and by creating web based educational tools.

As we have an undergraduate student as a member of our team, we have the opportunity to participate in several tiers of research conferences/events at which our work can be displayed. The first tier event is the Undergraduate Research Symposium. This event is held by University of Toledo and consists of all summer undergraduate research participants at UT presenting their results. This event will provide another means for displaying our message to a diverse audience. The Symposium consists of motivated undergraduate students studying varying fields, ranging from art to physics. This larger affiliation holds the potential to expand our work even further, particularly to the up and coming academics represented by the undergraduate community. The second tier of the undergraduate program is the Posters at the Capitol event, at which chosen researchers will have the opportunity to discuss their results to state legislative officials in Columbus, Ohio. Given this opportunity we can truly sway the minds of key figures to implement some of these sustainable technologies that are needed as we progress forward as a holistic society. The third tier of progression, and even greater still, is the National Conference for Undergraduate Research. This conference quite possibly will provide our largest route of exposure as it is a national event. With political and technical professional in attendance there is no better audience that would need to be impressed toward the implementation of technologies such as rainwater harvesting systems.

The fourth annual Sustainable U conference for Northwest Ohio is being held at the University of Toledo. Regional professionals, industry leaders, as well as interested audiences are all welcome to attend this event. Our team's work is going to be presented at this event to again broaden our horizons and expand our research network. As this conference is specific to sustainable designs, we anticipate a highly interested audience, one that will have great respect for the work we are doing and motivated to implement some of our findings.

In order for our research to continually be a part of the local green building community we submitted an article (Appendix C) to be included in the Northwest Ohio USGBC Annual Summer

Newsletter. Through our submission the article was accepted and included in the publication. The article focuses on the highlights and progress of the Research to Practice Program and our team's commitment to sustainable technologies. As the recipients of the newsletter are progressive members of the community, the exposure from this newsletter was well received.

The University of Toledo academic staff has long been an outreach program to local high schools. Our team leader Dr. Defne Apul has been a mentor for some time and continues to motivate the local youth. With our research and developed tools we wish to intrigue not just a higher educated audience, but younger generations as to stimulate their interest as they pursue their educational goals and future careers. Creating a sustainable future is no easy task and requires the involvement and collaboration of all ages, generation after generation. Through outreach activities, programs, and volunteer efforts such as this, our communities can become involved and sustainable ideas will soon become as common as curbside recycling.

"Nothing so needs reforming as other people's habits"-Mark Twain

For our outreach to extend beyond our physical presence, our team created a webpage as a means for our work to be displayed. Through the motivation of our team leader, a sustainability engineering class has become part of the engineering curriculum at University of Toledo. The results of our work were constructed as educational tools and they will be used as such. The EEAST model as well as our statistical results and findings will be used in the classroom to both educate and intrigue students on research programs such as the Research to Practice Program.

6.7 EEAST and LEED Rating System

Our Phase II Research is highly dependent upon the LEED ranking system. One of our team's main goals and deliverables was developing an effective way to convey our research in terms of LEED. The EEAST model has been developed to the point where it will generate the approximate aggregate water savings within a building. With this generalized information EEAST computes the preliminary LEED Water Efficiency and Sustainable Sites that can be expected from the five scenarios outlined.

Pending the completion of LEED v4, LEED – NC Version 2.2 was used as a benchmark. The credits that can be attained through this system are the SS Credits 6.1 and 6.2, which outline stormwater management practices, and WE Credit 1.1, 1.2, 3.1, and 3.2, which emphasize the reduction of centrally provided potable water in irrigation and aggregate building supply. Rainwater harvesting systems reflect the benefits of all of these credits while composting toilets would only be considered in the reduction of potable water provided for building use.

6.8 The Teaching Story

This entire project has been an education experience, from the advisors, team, and to the intended audience. The ultimate story we set out to teach was that of a sustainable society through design principles, however it evolved into much more. Our team realized that technology is not the ultimate solution. Ethics and personal action must be taken into consideration. Human accountability is of paramount importance if any sustainable technology or plan is to be implemented. All the research in the world could be performed, but without the research team's push toward practicing their research results, the research is essentially useless. By the same token if society is not willing to make changes and sacrifice a little now to gain a lot later, which is what some of the sustainable designs call for, then again the research can be rendered as unviable as it will not be utilized by the population.

Some of the results that our team had were quite surprising. Before modeling our team's biggest assumptions were in the highest and lowest forms of energy consumption and carbon emissions. Our initial assumption was that the dual piping network required to switch between centrally provided potable water and the rainwater harvested provided by the cistern would be the greatest energy cost and construction heavy process. As it turns out, this piping retrofit is quite simple and does not require or emit greenhouse gases nearly as much as originally believed.

On the other hand our initial thoughts were that cistern sizing, construction, and placement would not be energy intensive. Our results again proved us wrong. Our investigation proved that the manufacturing of the steel cistern and required polymers is actually the most energy intensive and pollutant phase of the process. Beyond the construction of the tank, the placement requires a concrete pad to be poured in order to stabilize the weight of the cistern, including the weight of the rainfall once captured and the cistern is at capacity. The pouring of the pad showed to be equally as problematic. Having these facts known we can educate those who wish to be environmentally friendly in future designs which may be unrelated to rainwater harvesting systems or any other portion of this research.

Which is more in cost and energy: dual piping or the cistern? Most LEED professionals would stay away from rainwater harvesting due to dual piping requirements but our results show cisterns are the major culprit.

7. Challenges and Solutions

Although our team was very structured and enjoyed the ease of routine, time conflicts often presented a challenge. With team members being so actively involved in the community time commitments often overlapped. Team members also held part and full time jobs as the research project moved from its' inception through continued work phases. These time conflicts were often not substantially detrimental to the teams' progression. Through proactive communication and our established schedule's we were able to remain on track. If a team member were to miss a meeting emails outlining the items and topics discussed were sent to that individual. If it was necessary some members of the team would meet outside of the group in order to bring that member up to speed.

As our team consisted of members from different backgrounds often time's individual members had different opinions on subject matters. We encouraged these opinions as the more who submitted input, the better the results would be to a varying audience. The challenge lied within incorporating all of these opinions in a clear and concise manner. Through the experience of our team leaders as well as informed discussions our team was able to manage our diversity extremely well.

Apart from the different backgrounds our team consisted of, within some fields we had participants of different age and academic progress (undergraduate, masters, etc.). This again strengthened our team as we were able to consider the opinions of a wide field. At times this was a challenge which needed to be addressed as some of the team members who were new to the research and report writing realm had to be introduced to resources as well as report writing skills such as Microsoft Office tips and tricks. The integration of all members and their skills into the team was well orchestrated through team management and mentoring. The experienced members of the team possessed knowledge of resources for the newer members to utilize in order for them to increase their capacity in the team's progression.

As with any project, deadlines can often times pose difficult to meet. Original time commitments may seem manageable, but then additional work and commitments present themselves and all of a sudden you are in a time crunch. This concept was no stranger to our team throughout this project. We are lucky to have such a highly motivated and intelligent team who embraced challenge. Our team's strongest resource has been the member's of which it is comprised. If one member was overwhelmed another would gladly help. Team advisors were always available to provide their insight and recommendations.

The concept of the project as a whole was a challenge. Decentralized water resources go against the established norm, which is never an easy task. People are comfortable. Communities enjoy the luxuries provided by the centralized system. Our solution to this is knowledge and the distribution of such.

As health and safety becomes even more paramount in regards to federal and regional regulations, the quality of cistern water and codes associated with such are becoming even more stringent. OAC3701-28-12 is a prime example. In order to purify the water entering the catchment system this code states that the first ten gallons of rainfall that would be harnessed must be diverted from the cistern. This method ensures that the majority of harmful residuals that would be collected by rainfall are swept clean and away from the cistern collection system. This added variable presented a challenge for our modeling strategy. In order to model and account for this affect, ten gallons of harvested rainwater would have to be subtracted from each rainfall event.

Modeling of composting toilets was a challenge. Composting toilets literature is not very well developed. There is almost no data on composting of toilet wastes. The data included in EEAST is from preliminary analysis and also the first software to model composting toilets.

Analysis of buildings that are used by a common set of people but still evaluated as one unit/facility poses issues/ambiguity in inputting the number toilets per floor or the number of floors. An example of this conflict is explained in the example used to explain EEAST while analyzing sustainable sanitation options for Nitschke and Palmer (engineering) buildings at The University of Toledo. Both buildings are used by a common set of people. However, a clear division of the number people using each building is unclear.

EEAST is a model. No model is true but some are useful. We created EEAST to be a useful model for the public and for the LEED community. EEAST provides general decision making criteria for those who would otherwise not have a tool to make such decisions. It is not easy to for companies that develop rainwater harvesting systems or for LEED professionals interested in rainwater systems to convince the public without specific figures/numbers on long-term benefits of using a new technology. This model allows generation of such figures and numbers that will help to give an idea on a life cycle basis.

8. Moving Forward

Consistent with our team's underlying principles and goals, we wish to continue our sustainable construction research indefinitely. Participation in this program has been great, but we do not see it as the end of the road or even as a toll booth. We wish to continue on researching and implementing sustainable strategies and designs to better the lives of communities and reduce our global carbon footprint. In order to achieve this goal, as previously mentioned, sustainable ideals must be integrated into a public forum. Progressive technologies such as rainwater harvesting systems, composting toilets among many others all need to be taken advantage of on a large scale and when it does make sense.

A more precise scope of work, consistent with our Phase II Research to Practice goals, is continued improvement. EEAST, as all models, has limitations. It is the intent of our team to minimize these hindrances and to optimize EEAST's relevance in the green building industry. Our society has a lot to learn and through the participation of universities and research teams in programs such as this one progress is destined to come. It is our goal to be at the forefront of this progress.

APPENDICES

Appendices A-E were provided as attachments to this report. Appendix I can be accessed at:

www.east.wikispaces.com. This report and all of its appendices are also available on our website in Appendix I.

APPENDIX A: EEAST Excel Model

APPENDIXB: EEAST Manual

APPENDIX C: Abstract submitted for presentation at the Ohio section American Water Works Association Conference

APPENDIX D: Summer 2012 Newsletter of Northwest Ohio Chapter of USGBC Including an article regarding our Phase II work.

APPENDIX E: Prezi Presentation

APPENDIX F: YouTube Video on Introduction to EEAST

APPENDIX G: YouTube Video on EEAST Financial Inputs and Interpretations

APPENDIX H: YouTube Video on EEAST Outputs

APPENDIX I: EEAST Website