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The Sustainable University: Sustainability & the Role of Higher Education

Final Course Report Fall 2013

EN 103 The Sustainable University
IDCE 30185 Sustainability and the Role of Higher Education
Clark University, Worcester, MA

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…… and special thanks to Jenny Isler, Clark Sustainability Coordinator

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Introduction

Jennie C. Stephens

This final report is a collaborative effort detailing the team projects of 16 undergraduate students enrolled in EN 103: The Sustainable University and 2 graduate students enrolled in IDCE 30185 Sustainability and the Role of Higher Education (the graduate-level section of this course) during the fall 2013 semester at Clark University. In addition to reading and writing about the challenges of sustainability and the role of the university in promoting sustainable practices in society, in this course students engage directly with the challenges associated with promoting sustainable behavior and fostering institutional and social change through semester-long team projects focused on specific sustainability initiatives within the Clark community. These projects have been an integral part of this course, and this final course report includes culminating details on the eight different semester-long team projects that these students developed in the fall of 2013.

Throughout the semester, students in the course benefited greatly from engagement and interactions with multiple individuals within and outside the Clark community. We extend appreciation to all of these people who have contributed to the success of this course and the students' efforts. Special thanks go to Jenny Isler, Clark's Sustainability Coordinator, who was an integral part of the course and contributed directly and indirectly to each of the student team projects. Thanks to Jenny for her effectiveness, dedication, and efficiency in communicating, responding and helping with so many aspects of the course. In addition we all benefited greatly from the valuable dedication, coordination, and contributions of the course Peer Learning Assistant Sharon Bort (GES '14) who took the course as a student during the fall 2011 semester and also served as a PLA during the fall 2012 semester. Thanks to Sharon for being a critical support person in each of these projects and for sharing so energetically her experience and passion. Thanks also to all the members of Clark University's Environmental Sustainability Task Force for their engagement with the course. I would like to express appreciation also to all the other individuals on campus who contributed to these students' work and to all of those who came to the students' final culminating public presentation on December 9, 2013.

During the semester, students in this class have explored the impact of learning at institutes of higher education and how that learning does not only occur in classrooms but throughout the campus community and space. Students have been exposed to and engaged with ideas about university policies and community priorities, as well as buildings and campus operations, and how these multiple dimensions all play a role in the role of higher education in society. We have explored how institutions of higher education have unique potential to catalyze and/or accelerate the transition to sustainability. The focus on the university provided a lens for students to examine how decisions with environmental consequences are made at institutions with complex structures. This situated students in a context for considering the broad role of education in sustainable development. And the course provided students with personal, direct connections and experiences facilitating learning about the challenges of promoting sustainability.

This semester has definitely been a learning experience for all of us. I recognize that many of the teams had initial hopes of accomplishing more within this semester than they have ultimately been able to complete, but I also hope that they have learned how common that is in many "real-world" experiences. The complexities of engaging with and contributing to these projects turned out to be greater than many were initially anticipated. But I am confident that the learning associated with these projects will exceed expectations in surprising ways.

Working with these students throughout the semester has been a pleasure. These students have worked hard and accomplished a great deal as they struggled with the challenges of promoting environmental sustainability at the individual, institutional, and community levels. While this report details the work done during the fall 2013 semester, several of these initiatives will continue to be developed and implemented by these students and others on campus beyond this semester. For up-to-date information about any of these initiatives please get in touch with me or with any of the students.

Thank you for your interest in these student projects and in the sustainability initiatives at Clark University!

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Rainwater Irrigation Initiative

Erick Bilides and Verna Zhao

Abstract

Rainwater runoff will be used to water the Clark University garden in effort to reduce the amount of Worcester City drinking water that has been previously used for this purpose. Rainwater harvesting provides an alternative for water usage in the Clark Community Garden and could improve water access for the community gardeners during the summer months. During the summer season when students are on break, stored rainwater could be accessed through a combination of both drip irrigation and rainwater catchment. *The Rainwater Irrigation Initiative,* composed of Erick Bilides and Verna Zhao*,* will implement a rainwater drip irrigation system in the Clark community gardens. The rainwater drip irrigation system will be used as a practical and educational model to show students, faculty, and the larger Worcester community the benefits of using captured rainwater. The rainwater drip irrigation system is an educational and practical model because it encompasses sustainable alternatives to water usage and will be fully functional at the same time. We wanted to show the communities of Worcester that *The Rainwater Irrigation Initiative* is inexpensive and can help save vast amounts of water. As for the garden members, we wanted to develop this project to help diminish the difficulty of gaining access to water. This project can also provide students with an example of how to invest in alternative sustainable practices while simultaneously teaching others the benefits of sustainability on campus. This semester our team accomplished several things: (1) secured funding, and (2) developed plans to install the system in the spring of 2014, and (3) established collaborative commitments for the installation. We have a plan to build Clark's first rainwater drip irrigation system in the spring of 2014 in effort to provide the school and surrounding community with an example of possible sustainable resource practices.

Introduction

A person's body weight is made up of two-thirds water, and without this molecule, a person would die in approximately three days to a week. The human brain and heart holds roughly 73% water, skin is 64%, muscles and kidneys are 79%, and the lungs are made up of about 83% water (USGS 2013). Since the beginning of human existence, our survival as a species has been sustained by earth's natural resources. Without this molecule, human existence would have never began.

The future of humanity will continually be shaped by access to these vital resources (EcoNews, 2012). Currently, about 2.7 billion people suffer from water scarcity for at least one month during every year. During these months, competition in these affected areas increases significantly along with the chance of violence. (EcoNews, 2012) Furthermore, due to rapid population growth and continued over use of natural resources, humanity has found themselves living in a world with life threateningly scarcity of essential resources. "The prospect of future scarcities of vital natural resources, including energy, water, land, food and critical minerals. This in itself would guarantee social unrest, geopolitical friction and war." (Klare, 2013). Due to the fact that the earth is made up of a finite amount of resources coupled with human activities that have depleted massive amounts of said available resources, it is paramount that people begin

implementing sustainable practices into their everyday lives. (EcoNews, 2012)

With global resources being diminished it is also necessary to understand what resources are of the upmost importance. In short, water is the most essential molecule for human existence. It is the reason why NASA's guiding policies in the search for alien life is to 'follow the water' (Ball, 2003). Without water, the earth's diverse species would not thrive and prevail. The world holds about 1.4 billion cubic kilometers (km3) of water but only 200,000 km3 is available for ecosystem and human usage. (Tran, 2013) That being said, these numbers become even more important once one takes into account the yearly increases of human population on a global level. At the present moment, human population is roughly 7.2 billion and has shown no signs of stopping. An agency for the United Nations has projected that Earth's human population will increase to 9.6 billion by 2050. Subsequently, by the year 2100, human population will exceed 10.9 billion. (Sullivan, 2013). Water is running out, which means there needs to be steps in place that save and utilize water in a more sustainable manner.

There are many ways one can use water in a more sustainable manner. One great way to save and amass the precious resource is through rainwater catchment. Although this system will be explained in full later on in this report, rainwater catchment systems offer an easy solution for people who live in a climate that may experience mid to high levels of yearly rainfall. In short, the system catches any rainfall that would fall off of a roof and stores the water for later use. This system helps to decrease human dependence on land water resources and would greatly reduce unnecessary water consumption if implemented on a large scale.

On a more local level, Clark University in Worcester, Massachusetts offers a place where these water saving solutions can be practiced. Clark University has been committed to environmental sustainability throughout its history as an institution. This claim is particularly noticeable with the University's new campus renovations, which have created numerous improvements to campus sustainability in 2013. Furthermore, Clark University has made the promise to have net zero greenhouse gas emissions by 2030. (Clark University, 2009) Clark University also has a community garden that is run by the student body and is located within the campus. The garden offers a spot where a rainwater catchment system could be put in place. Due to the rainwater water catchment system's construction site being at the community garden, a drip irrigation system will also be combined with the proposed system. This combination of rainwater catchment and drip irrigation will act as an educational model for students and faculty. The student body and the University administration need to continually see that sustainable practices are possible and can be easily implemented.

Worcester, Massachusetts is home to Clark University where we are working to install a rainwater irrigation system. New England is known for its abundant rain seasons, which makes it a perfect place to experiment with water saving practices. (Holmes, 2013) Worcester on average sees roughly 48.07 inches of rainfall, making Clark University a great place to install a rainwater irrigation system. (Weatherdb.com, 2013) The Rainwater Irrigation Initiative will utilize the abundant rainfall to provide the members of Clark University and the Worcester communities with an example of one way to capture, store, and use rainwater in a sustainable manner.

Background

Water conservation is important for a number of reasons; 1) without access to water, humans will die within a week; 2) using less water saves money; 3) saving water is critical for protecting the earth's natural eco systems from continued damage; 4) practicing water conservation saves on energy (Speer, 2012); and 5) active water conservation spreads awareness and acts as an educational model in supporting the importance of continued water saving practices. With this in mind, *The Rainwater Irrigation Initiative* has decided to combine rainwater catchment with a drip irrigation system at the Clark Community Gardens in Worcester, Massachusetts.

A rainwater catchment system is a method to catch and store rainwater for gardens or other uses. The rainwater is usually caught on a roof of a building through the use of gutters, and flows downwards into a holding tank. Due to the possibility of high percentages of acid rain, filtration devices are normally installed at one end of the gutter to help purify the captured resource. A down stem is then added beneath the water filter connecting the gutters to a gravity fed pipe system, which leads straight to a holding tank. Once captured within the holding tank the water can be directly accessed when needed. (Water, 2013). Rainwater catchment is used for various reasons, such as helping to minimize drinking water consumption and to hold over regions that experience yearly dry spells.

The *Rainwater Irrigation Initiative* is combining the process of rainwater catchment with a drip irrigation system. "The beauty of drip irrigation is that it drips. It doesn't spray or gush, sending a lot of water where it isn't needed. Instead it slowly drips where the water does the most good, thus saving both water and money" (Pohly, 2010). This is one main reason why many small farmers used drip irrigation systems, because it is affordable, saves water, and helps regulate watering cycles for plantations. Drip irrigation systems are not as common within the northeast because there is not as high of a percentage of large farms as comparably to the south and Midwest of the United States. Secondly, the heat in the south is also more intense and water is needed more frequently, especially for large agricultural farmers. It is difficult to control the amount of water plants are taking in from a hose or a sprinkler but these problems become nullified by using a drip irrigation system.

Many colleges and universities including New Mexico State University, Colorado State University, University of Missouri, and Clemson University have already installed drip irrigation systems. These drip irrigation systems have been largely successful with some schools stating a 50% reduction rate of water use through the introduction of a drip irrigation system (author, 2013).

Clark University has a long history of engagement with environmental sustainability, especially within the last decade. Over the past couple of years Clark University has been experiencing massive renovations throughout it's campus. This includes expanding upon the Bickman Fitness Center, upgrading its heating system, installing "hydration stations", and implementing paper free air dyers. (Clark University, 2009) Although these are not all of the renovations, these examples show Clark University's commitment to sustainable practices, further making Clark University a great place to experiment with water saving initiatives. Due to constant construction at Clark University, the school has become more sustainable. Especially in the US, there has been a continued push to transform the nation's educational system to prepare students to

change the world in which they live. (Haines, 2010) Buildings such as Lasary and Blackstone Hall are energy efficient, which helps not only save energy and demonstrate sustainability, but also builds a better learning environment. Besides Clark University's attention to maintaining sustainable campus architecture and energy systems, the university also encourages sustainable thought amongst it's students with courses such The Building on Previous Student World.

Our team's success this semester was made possible because we built upon the work that previous students have accomplished. The Sustainable University's 2011 rainwater catchment team, *The Rain Garden Initiative*, successfully implemented a rain garden at Clark University's Admissions Office, located on the intersection of Maywood and Main Street. The group constructed a rainwater catchment system using the roof of the admissions building. The catchment system captured the rainwater and fed it directly into a rain garden of which the team had built. The team used the rain garden to diminish the overall effect of storm water runoff and the possible dangers it can pose. Quality of water is affected by storm water runoff due to the fact that runoff can carry with it bacteria, viruses, and other hazardous materials into our water supplies. If our water supply is contaminated, the water becomes a safety concern and would need to be tested before use. If left unchecked, contaminated water can have negative impacts on human and environmental health. (Boyle et al., 2011) After reviewing the results and success of *The Rain Garden Initiative*, *The Rainwater Irrigation Initiative* has decided to use their accomplishments as a blueprint for our project, but instead of using a raingarden to collect the runoff; our plan is to use safely filter the captured runoff for use in the Clark Community Gardens.

Annual Rainfall Averages for Worcester, Massachusetts (inches), (Weatherdb, 2013)

January= 3.49
February= 3.23
March= 4.21
April= 4.11
May= 4.19
June= 4.19
July= 4.23
August= 3.71
September= 3.93
October= 4.68
November= 4.28
December= 3.82
Annually= 48.07

Process

This is a semester long project with a goal of implementing a rainwater drip irrigation system in the Clark Community Gardens. We want to contribute to raising awareness about use of land and resource sustainability while simultaneously enhancing education in Clark's sustainable functionality. Furthermore *The Rainwater Irrigation Initiative* seeks to provide a concrete example of successful rainwater catchment systems

in response to Clark University's continued push for sustainable practices on campus grounds.

As of late September and early October, our team searched for people who could help provide professional knowledge on the subject of rainwater catchment. The Rainwater Irrigation Initiative met with Michael Dawley, the director of physical plant, and told him about the project. Michael Dawley has helped provide the team with the necessary skills to navigate around Clark University's campus regulations and policies. With his help and advisory, our team has decided to put the entire system above ground because of Worcester regulations and the fact that it can provide a visible educational model for students, faculty, and the broader Worcester community.

After meeting with Dawley, our team asked the coordinator of the community garden, Emily Smela, for permission to install the proposed system in the community gardens. Members of Clark Community Gardens will operate directly with our project so it is necessary to effectively communicate our goals amongst the club's members. The members of Clark Community Gardens will be allowed to volunteer their help in constructing the system but currently they have offered advice and criticism as to where the system should be installed. At the moment Erick Bilides, Verna Zhao, and Clark's physical plant will be the ones to fully implement the proposed system. The club leader, Emily Smela, allowed us to continue with our proposed goals and has continually provided us with feedback. She has mentioned the difficulty of bringing water to the gardens throughout the seasons since water is not directly accessed near the gardens, "it takes at least two people to get water, and one has to always stay behind to turn off the water while the other one is signaling when to stop." The community garden currently has five beds and through coordination with club leader Emily Smela, the team has decided to use only two of the five beds. We plan to have an opening on the tanks as well so the garden club members can directly get water from the tanks into the beds that will not be irrigated. The decision was made in effort to leave the last three beds upon for further experimentation in terms of implementing other various sustainable practices. *The Rainwater Irrigation Initiative* hopes to inspire future projects within the community gardens and is actively looking for new ideas to be discussed in coming years.

Jenny Isler, the Clark Sustainability Coordinator, discussed combining water catchment with drip irrigation in the community gardens with *The Rainwater Irrigation Initiative*. She has directed the our team to other outside help such as Sean McCartney, a grad student at Clark University who has previously designed cistern drip irrigation systems in California. He has helped the team look into various pipes, filtrations, tanks, and other materials that our needed to build the system. McCartney further explained possible problems that the team may face such as inadequate pressure levels for the irrigation system. McCartney explained that pressure and gravity is key in making sufficient water levels reach the necessary garden beds. He has also advised us into researching piping material that can endure the colder seasons that New England experiences.

The last organization that the team met up with was the Student Sustainability Fund. We met with the SFF's leader Sharon Bort, who helped us prepare the necessary material needed for future funding. With help from Sharon Bort, we successfully submitted our applications for funding on October 1, 2013, and subsequently the second application on November 1, 2013. The team met up with SSF and they have given the

members of *The Rainwater Irrigation Initiative* positive feedback on the project. Secondly, SSF has awarded the team with $700 USD to be used in acquiring the necessary materials.

The plan for a rainwater catchment system coincides with Clark Universities continued push for green alternatives around campus. Furthermore, the garden is a perfect site to experiment with resource sustainability and will showcase both the positives and negatives of rainwater catchment systems. The proposed system once operational, could be used as evidence to support the continued usage of such projects throughout the campus, specifically Alden Quad, which is due to be renovated this coming summer. In essence, the project fits perfectly within the realm of Clark's current and future sustainable agenda.

At the moment Clark University is investing in a climate action plan for 2030 that will reduce net greenhouse emissions to 0% by this date. (Clark University, 2009) This rainwater catchment system is a part of this goal because it helps increase sustainable education throughout campus and provides a visual example to students, and faculty about sustainability. Small projects such as rainwater catchment systems can help students visualize and observe sustainability on campus rather than just hear about sustainable practices. Students can participate and work on projects similar to rainwater catchment as well as other sustainable practices on campus and around the community.

Results

This next section of the report will show the reader, through graphs and proposed blueprints, how the finalized project will look and work.

Future Plans

Timeline from December 2013-October 2014

December 2013- Further revisions to our building plans as well as alternative arrangements for pipe layout will be made.

January 2014- Purchase required items found in list 1.0. Construction in terms of framing will commence and be completed by the end of the month.

February-March 2014- Clark University's Physical Plant will install the necessary gutter and filtration system on the garage in the back of Clark's Alumni house. [Found in figure 1.0.]

March 2014- Finish building *The Rainwater Irrigation Initiative* project

April-October 2014- Record the amount of rainfall the system collects and uses each month the system is operational. The systems operational status is subject to change due to uncontrollable variables such as rain storms, flooding, and human error.

September 2014- Host a presentation of the system in operation, followed by a Q&A session with The Sustainable University's class of fall 2014. The founders of *The Rainwater Irrigation Initiative*, Erick Bilides and Verna Zhao will conduct the

presentation.

The Student Sustainability Fund has allocated $700 USD to *The Rainwater Irrigation Initiative* for construction of the project. Some of these funds will be used to host the above mentioned presentation and Q&A with The Sustainable University's class of 2014. *To view The Rainwater Irrigation Initiative's fund proposal see 1.0 in the Appendix*

Figure 1.0
"Finalized" Blueprint of rainwater irrigation system

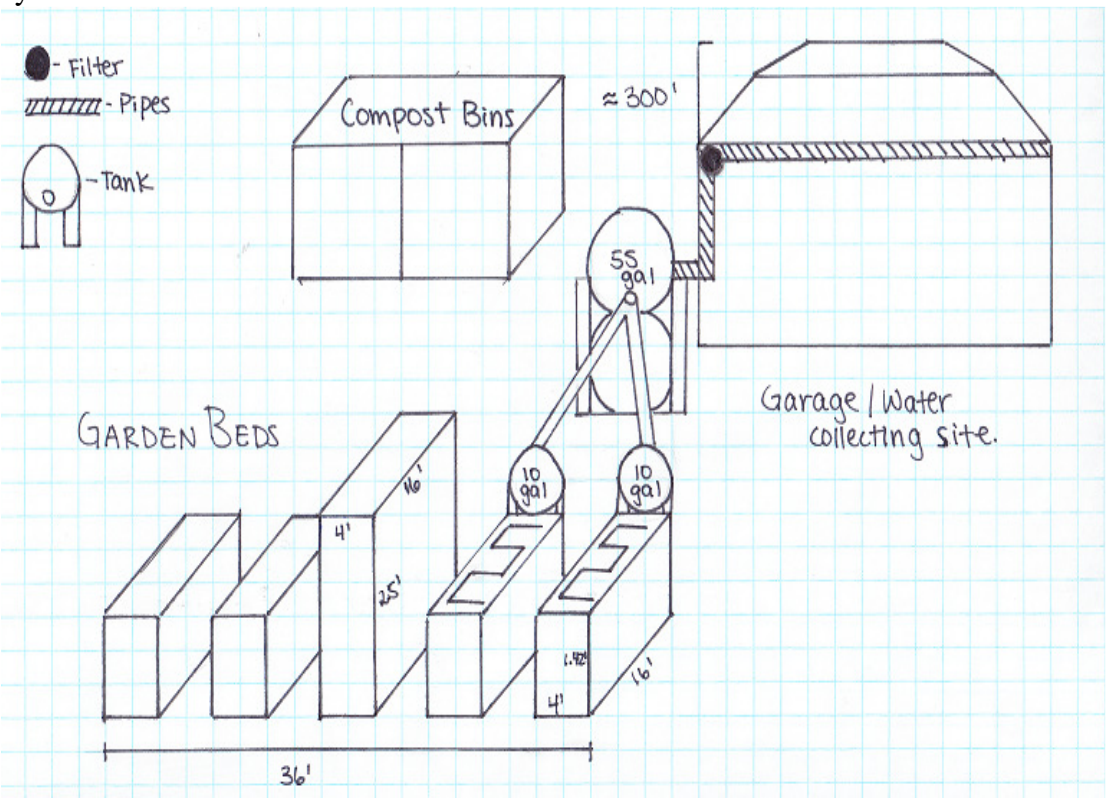

Figure 1.1
Garage/ Water Collecting Site

- Attached gutters will collect rainwater
- Approximately 300 square feet

Calculation: Harvested = Catchment Area (ft2) X rainfall depth (in) X 0.623
Rainwater Conversion

300(ft2) X 48.07 X 0.623 = 8984.283 harvested gallons if system is left operational full year

300(ft2) X 28.57 X 0.623 = 5339.733 harvested gallons if system is operational from March through September

(Weatherdb, 2013) (Lancaster, 2013)

Materials needed: (#) = Amount of material needed

In relation to water catchment system:

(1) Gutter (PVC)
(1) Screens for Gutters
(1) Downspout
(1) Mesh Filter
(1) Carbon Filter
(1) Leafslide rainhead
(1) 90mm dual fit first flush water diverter
(1) 55 mm water diverter downpipe
Roughly 100 feet of PVC piping/ diameter of 55mm
(2) 55 Gallon Drum (Polyethylene)
(1) Tank overflow outlet 55mm X 55 mm with 90-degree bend

In relation to the drip irrigation system:

(2) 10 Gallon Drums (Polyethylene)
(2) Tank Covers
(7) Release Valves
(2) 12 ft long flexible drip irrigation piping
(½" in-line drip emitter tubing)

In relation to building materials:

(4) 50 lb sandbags
(40) 8 ft 2" X 4" of pressure treated wood (Southern Yellow Pine)
(10) 8ft 2" X 6" of pressure treated wood (Southern yellow Pine)
(4) 4'X 8' X ½" pieces of plywood
(4) Door hinges

Due to the expectation of large quantities of water collection, summer of 2014 will act as a pilot run to make sure the system can handle the estimated gallons of water collected. There will be an initial holding tank of 55 gallons followed by two subsequent holding tanks of 10 gallons each. These two tanks will be connected to the drip irrigation system and will be controlled by two hand-operated release valves. In preparation for heavier rainfall there will be another 55-gallon holding tank, which will secure any rainwater overflow that the initial 55-gallon holding tank may experience. A cutoff valve

will be placed below the down stem in case of a full system overflow, which will immediately stop further rainwater from being collected. Once the project is fully built and implemented there will be an event, organized by Erick Bilides and Verna Zhao, to showcase what has been done. This event will act as a presentation to show the system in full operation and the benefits of sustainable water usage. A newsletter will be written by Erick and Verna and will be sent out in a mass email to Clark University's student and faculty body in hopes of generating press. The time and date of this "debrief" is currently unknown, but the Clark Administration, faculty, students, and the Worcester community will be invited for the viewing. If the project remains successful throughout the summer *The Rainwater Irrigation Initiative* will welcome next year's class of The Sustainable University to a secondary showcasing. This event will show students possible projects they too can implement during their semester in the course. This presentation's main purpose will be educational, in that it will show students that the proposal's they work on throughout the semester can come to fruition. Lastly, the students will learn one way in which they can practice resource sustainability at Clark University.

Conclusion

The Sustainable University has given the course's students a chance to work with faculty, staff, and other members of Clark University's student body. The idea of sustainability on campus has given us the opportunity to propose and implement a sustainable project to help raise awareness to the communities of Clark University and Worcester. The rainwater irrigation system will also be the first of its kinds on campus and the team is excited to show the community its positive attributes. The implementation of the rainwater irrigation system has yet to be built due to New England's unfavorable weather conditions in the winter. With this grace period being allotted, *The Rainwater Irrigation Initiative* will continue to research ways in which to make the system more efficient and accessible for students, and by spring of 2014, with provided funds from SSF, the rainwater irrigation system will be officially built and operational.

There are many projects including this rainwater irrigation system that can help reduce and utilize the amount of runoff water on campus. This project is a continuation of the many sustainable projects that have come to fruition through The Sustainable University course. If the project is successful, *The Rainwater Irrigation Initiative* plans to adapt the project to other various locations around campus, such as the Alden Quad, which will be going through renovations during the summer of 2014. Overall, the team hopes to raise awareness on the many available possibilities for resource sustainability in a university setting. The team, through the implementation of the rainwater irrigation system, seeks to inspire the students and faculty of Clark University to continue engaging in projects that increase campus sustainability and further push the University to facilitate and produce new sustainable projects yearly.

Acknowledgements

We thank Jennie Stephens, *Advisor* Jenny Isler *Advisor*, Sharon Bort *Advisor and SSF coordinator*, Kerry Burke *Garden Club member and Alden Quad led project manager,* Chip Pybas *Clark Grounds Manager,* Mike Dawley *the Director of Physical Plant,* and Sean McCartney, *Graduate student at Clark University* and *designer of drip irrigation systems*

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Appendix

1.0
SSF Funding Proposal
Project Overview

A rainwater catchment system is a method for catching and storing rainwater gardens or other uses. The rainwater is caught on the roof of a building and travels into gutters subsequently flowing to a down stem where it will be filtered. There will be tanks at the end of the pipe storing water and when needed, it can be directly pumped out into the gardens.

The Clark Community Garden has helped provide students with freshly grown herbs and vegetables over the last couple of years. The garden not only allows students to eat locally but, also gives the Clark community a place to practice green and sustainable initiatives. In hopes of continuing this educational approach to sustainability our group plans to install a rainwater catchment system at the garden. During the summer months at Clark University, watering and maintaining the garden becomes a serious issue. Therefore the need for on-site water resources is necessary. Presently the garden is being maintained by clean drinking water, which is an unnecessary waste of resources. The proposed project would eliminate the need for wasting drinking water by utilizing the run-off from a neighboring roof. The rainwater catchment system would collect the rainwater and irrigate it directly to the garden below.

Our plan is similar to two other previous projects, one on campus and on at another university. At Clark University, there was a previous project that was implemented on campus called "Rain Garden Initiative". The idea of their project was to reduce runoff water from the roof of Clark's Admission building into a garden. This is one way that Clark has created an alternative using runoff rainwater to water the garden. The other project is currently happening in the University of Arkansas. Arkansas's weather is worse than here in New England and because of many droughts they have implemented a system in their school hoping to eliminate the usage of clean water and use rainwater instead.

Our rainwater catchment system will be implemented in the spring of 2014. We are hoping that this system will help influence students on and off campus, therefore we want this project to stay up as long as possible. It is considered a test trial as well because we want to further our research and implement a system in the Alden Quad.

We have submitted our first application to SSF on October 1, 2013. We have met and received approval in continuing applying for loans.

Partners *(Provide a list or description of who else is involved and extent of their involvement)*

Jenny Isler *Advisor*
Sharon Bort *Advisor*
Kerry Burke *Garden Club member and Alden Quad led project manager*

Mike Dawley *the Director of Physical Plant*
Patricia Handrahan *Office Manager*
Rachel Sorenson and Xavier St. Pierre *previous students who worked on water projects designed a dripping irrigation system.*
Emily Smela (Student club) *Group leader of the community garden at Clark University*

We have received necessary approval from Mike Dawley, *Director of Physical Plant*. He thought our idea was great and would be easy to implement. We have also spoken to Emily Smela, *leader of the community garden at Clark University,* about the rainwater catchment system and she also approved. She saw that it was a necessary system to have, especially since many of the gardeners are gone during the summer month. We have spoken with Sean McCartney because of his previous experience with installing and construction drip irrigation systems. Our idea is focused on combining a rainwater catchment system with that drip irrigation.

If we implement the system in 2014, we can test for a year to see how sustainable the system is. We can improve along the way and see what we can do to help make the system better. Our hope is that this project can last on campus and move onto the Alden Quad.

The rainwater catchment system in not needed for much maintenance until winter time when community garden staff can easily take it down. There will be directions of how to. There is a previous project of how runoff rainwater is reused in a rain garden. As of this year, there is no connections with other projects in the sustainability course. Our project is part of *The Sustainable University* and Jenny Isler has informed us to further our project research.

Budget and Fundraising *(provide detailed budget and discussion as below)*
Amount Requested: $700- 1000

Pipes (metal and flexible pipes)
Filter
Holding tanks (2- 10 gallon tanks and one 55 gallon tank)
Gutters
Dripping Irrigation
3 Release Valve
Wood for framing
Metals racks for holding tanks
End Caps
Metal Clamps
Wire Loops to hold drip line when it's empty

If SSF is unable to fund the necessary resources, the project can still continue. The minimal cost of our project is at least $700.

Timeline *(if possible use a calendar or Gannt chart to illustrate the project planning and implementation steps)*

We want to implement this system ourselves with the help of volunteers. Erick Bilides has previously worked in the field of construction. He has gathered volunteers to help put up the rainwater catchment system.

First, install the pipes, gutters and filters. Have them go along one side of the adjacent garage. The pipes will hang along the side of the house and extend across a fence. Attach the pipes with metal clamps along the fence until it reaches the garden (about 40 feet). The larger 55 gallon tanks will be held with metal racks. At the end of the pipe, it will be connected to the tank. That tank will then connect to two smaller tanks, 10 gallons each, and the irrigation system will connect from there. We will ask Sean McCartney to help install the drip irrigation system in the gardens.

Metrics: Tracking and Reporting *(how will you measure the impact of the project? Remember SMART objectives)*

We start out by measuring the amount of water each tank can hold after a rainstorm, and average out how much rain will be caught for a whole year. With that water, we can also measure how much water was used in the beds. Because each season there will be different amount of rain and different amount of water needed for the beds, we can easily measure that. We can account for how much water is being saved after a full year of analysis.

Outreach and Education

We will use a portion of the money funded to have an "open house" after the system is implemented in the garden. Apparently not many people know about the community gardens and it can help raise awareness that one is located on campus. Because the tanks and pipes will be above ground and visible to the public, on and off campus, it can be easily seen. Other students and the public are welcomed to come and hear why the implementation is important to the gardens. Throughout the coming years we can continue hosting events to educate people on sustainable gardening and green living.

Additional/ Relevant Material:

We have received approval from both physical plant and the community gardens at Clark University.

Sustainability Hub Assessment

Matthew Alvarado-Ross

Jennessa Piccirilli

Abstract

This project focused on the Sustainability Hub which recently opened on Main St. in Worcester, Massachusetts in a space donated by Clark University. The Hub, which helps promote National Grid's Smart Grid pilot in Worcester, also acts as a community space for sustainability education, and a model home built on the most advanced energy-efficient technology and recycled materials. After employees at the Hub expressed interest in getting input from Clark students on potential improvements to the sustainability of the Hub, we decided to perform an assessment of sustainable practices in the Hub and then report on our findings. The goal of the project was to assist the Hub in becoming as effective of an example of sustainable practices as possible and potentially help in the seeking of LEED certification from the U.S. Green Building Council. Our findings were that the Hub is, in fact, running extremely efficiently already, but could make use of slight changes to improve consumption of energy, management of waste and other sustainability issues.

Introduction

Environmental sustainability is becoming increasingly important as we all are experiencing more extreme weather conditions associated with climate change as well as other forms of environmental degradation ("New analyses…" 2013). As the world population grows, the need for more resources also increases. The United Nations, established on the principle of achieving peace and development, did not discuss sustainability in detail until the year 1972 ("The History…" 2011). A sustainable practice involves methods that do not use up or completely destroy natural resources. A problem with addressing sustainability is how slowly support has spread. Atul Gawande, an author for the New Yorker, makes a valid point of how certain innovations spread fiercely and thoroughly while others gradually spread. Environmental issues regarding sustainability and climate change were slow to gain the public's attention (Gawande 2013). The New Yorker gives the example of surgical anesthesia, a product modern day society is highly aware and informed of. In only a few years virtually every hospital was using anesthesia (Gawande 2013). Anesthetics are an immediate solution to an obvious problem, whereas environmental issues have less obvious solutions. Also, people tend to feel disconnected from issues of sustainability because the effect on them is not immediate. Therefore, the spreading and sharing of ideas about sustainable living is crucial to gaining widespread support. In Worcester, Massachusetts, a partnership between Clark University and National Grid has resulted in a new way of spreading those ideas. This came in the form of a "Sustainability Hub", a community space in which local Worcester residents and students can visit and learn about sustainable living and a rapidly changing electrical system (Homer 2013). The Hub is also a primary space form National Grid to promote their Smart Grid pilot in Worcester. The program involves the

installation of Smart Meters around Worcester. These are electrical meters that communicate with the electrical company so that both the company and customer can have a better idea of how much energy is being used and when ("National Grid…" 2013). There is some controversy as to whether the meters are safe because of radio frequency emissions that come from them (Bird 2013). The Sustainability Hub is set up as a model home making heavy use of recycled materials and energy efficient appliances. As an example of ideal sustainable operation, we feel it is critical for the Hub to maximize its sustainable practices so as to help community members learn from those practices. The project involves a general assessment of sustainable practices within the Sustainability Hub to ultimately be compiled in a comprehensive report of suggested improvements.

Background

In Worcester Massachusetts, a National Grid Pilot has been kicked off called Smart Grid which will involve installing Smart Meters in thousands of Worcester homes (Overton 2013). These meters communicate in real time with the company so that customers can track their energy use by time (Stephens 2013). Controversy has emerged from the program, however due to a number of concerns with the meters (Wright 2013). For one, it is thought the radio frequencies emitted by the meters could cause serious health concerns. Other issues that have been discussed include the invasion of privacy associated with the installation of meters that so closely track energy use within a home and the extent to which homes have been equipped with smart meters without the knowledge of the homeowner (Wright 2013). One thing is certain though, if some of these problems are resolved, the Smart Grid system could represent a highly innovative change to the electricity infrastructure in Worcester and cities around the world. This is particularly appropriate in Worcester, a city that has recently committed to finding such innovative environmental solutions (McCauley et al 2012). Such was the goal at the Green2Growth summit held in Worcester two years ago.

In partnership with Clark University, a higher education institute known for its involvement with the community, National Grid has renovated space on 912 Main Street to promote sustainability. The goal is to encourage the community to take environmental issues into their own hands and change everyday choices and habits to better the community around them. The hub is a space intended to be used by local organizations, groups and people that can share effective practices of sustainability (Homer 2013).

A team created by a Clark University class is assessing the Hub for its practices within the space. A structure built to promote sustainable practices should ideally demonstrate those practices. In collaborations with Clark National Grid intern ambassadors at the Hub, the team is walking through the hub at different times evaluating the hub efficiency. To make the assessment a checklist of questions was constructed that focuses in on sustainability. The results of the walk-through assessment will be put into a report for the employees of the Hub to take advantage of.

Being that the Sustainability Hub is brand new, there is no history of such initiatives from Clark University. However given the support the Hub has already gotten from Clark ambassadors, it is clear that the Clark community has a willingness to maintain interaction with the Hub.

Process

The original project the team had attempted was to create a video and pamphlet promoting the consumption of sustainable and local foods to be displayed in the Hub's community space. However, we realized that many Worcester organizations already have such materials prepared, and it would be more efficient to contact those organizations and connect them with the hub. So, a new project emerged for our team which was the assessment of sustainable practices in the Sustainability Hub. By reviewing sustainable practice checklists made for businesses and the list of credentials for LEED certification we compiled a list of sustainable practices that were relevant to the Hub. By walking through and observing and then speaking with Hub employees about other practices, we determined which sustainable practices were taking place already and what changes needed to be made. We divided our observations into the categories of waste management, resource consumption, and community outreach. A comprehensive report of the findings was put together and sent to Sustainability Hub employees. The group is prepared to continue to support the Hub in its development towards ideal sustainable operation.

Results

We have prepared a two-page summary document with recommendations that we have given to the Sustainability Hub National Grid coordinator, Rita Moran (see Appendix). In this document we summarized our finding and provided specific suggestions that we hope will be helpful.

Our work found that the Hub is already operating at high efficiency and with a clear commitment to environmental consciousness. However, the following basic suggestions were made to help the Hub improve even more.

To improve waste management, it was suggested that the Hub eliminate use of disposable containers such as plastic bottles and paper cups, and to consider alternative to paper towels such as cloth towels. The waste created by paper towel dispensers is immense and significantly more than the energy used to wash cloth towels. Even water is saved because of the vast quantities of water used to produce even recycled paper towels ("Wage War…" 2013). We also have encouraged the Hub to make recycling and composting a greater priority in their displays. The recycling bins within the facility are not prominent and do not come with guidance for how to separate recycling. This is an important in-home sustainability practice and should be highlighted, because public understanding will greatly improve people's motivation and performance in recycling (Thomas 2001).

To improve the Hub's resource consumption, we suggest that the Hub install a system of automatic lights so that not all the lights are on all day. It would also be advised that the large television display screens in the Hub be put to sleep when not needed. At present, both lighting and most appliances are left on throughout the Hub's hours of operation. Practices such as automatic lighting systems have been estimated to save as much as 38% of the energy used by lighting (Dilouie 2013).

The final area of potential improvement for the Hub is its community outreach. Without the regular support of the community, the Hub will not accomplish its goal of promoting sustainability for families and students in Worcester. Possible ways of increasing community involvement in the Hub could be through the creation of a user-

friendly website and outreach through email. Other miscellaneous changes could include the installation of a bike rack to encourage visitors to use emission free transportation, which would complement the electric vehicle charging station that already exists outside the Hub. This is also already aided by the heavy presence of WRTA bus stops near the Hub.

Conclusions

Many of the changes suggested in the report submitted to Sustainability Hub employees were fairly basic, but we feel they could really improve the Hub's general operations. Moving forward, we feel it important to continue supporting the Hub. To do this we plan to continue our outreach to other organizations that may want to display materials about sustainability ideas in the Hub. Creating these connections should help the Hub's appeal. We are thrilled to play some small role in helping launch such an innovative tool for sustainability education.

Finally, we hope to encourage National Grid and the Sustainability Hub to look beyond ideas and innovations that are beneficial to the company. Since we believe that the Hub represents a true commitment to environmental change, changes such as the inclusion of demonstrations on the use and potential of renewable energy production in homes would further this goal.

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Fossil Fuel Divestment at Clark University

Sarah Maloney, Matt Sullivan and Rose Watts

"Invest. Divest. Remind folks there's no contradiction between a sound environment and strong economic growth."
-President Barack Obama

June 25, 2013 at Georgetown University
Sourced from Gillis, 2013.

Abstract

Climate change is a growing problem facing our world, and the burning of fossil fuels is a main cause of these climatic disruptions. As the world begins to transition away from fossil-fuel reliance, one effort to reduce the power and influence of fossil fuels in our society is divesting from fossil fuel companies. Fossil fuel divestment campaigns at colleges, universities, and other institutions such as religious groups and small governments have been growing in recent years (Fossil Free, 2013). Through the course of this project our team researched the challenges and benefits of considering divestment from fossil fuels at Clark University. We conducted general research about divestment both in general and at specific institutions. We contacted people from other schools that have successfully divested. In addition to finding Clark's investments we also met and talked with representatives from the student group called "Students for a Just and Sustainable Future" at Worcester Polytechnic Institute to learn about their experience in pursuing divestment. Overall, our project provides information, including both the challenges and benefits of divestment, relevant to considering a fossil fuel divestment campaign at Clark University.

Introduction

Climate change is an important indicator of society's reliance on fossil fuels for energy practices. These practices, which consist of the combustion of fossil fuels for purposes like transportation, electricity, and heating production, add heat-trapping greenhouse gases such as carbon dioxide, methane and nitrous oxide to our atmosphere (World Wildlife Fund, 2013). These gases increase the greenhouse effect and disrupt the natural, global carbon cycle (World Wildlife Fund, 2013). Climate change is also considered a risk factor for increasing both the severity and number of extreme weather events (Perlberg, 2013). We rely every day on the use of fossil fuels for many sources of energy including gasoline for our cars, oil for heating our homes, and coal for generating electricity.

Fossil fuel divestment is a new and growing movement that is gaining momentum on college campuses across the country (Fossil Free, 2013). Fossil fuel divestment is also a process that is carried out generally over a period of years (Humphreys, 2013). An organization called "Fossil Free", which is the leading organization in the divestment movement, defines divesting by removing investments based on "carbon in proven oil, gas and coal reserves" (Fossil Free, 2013).

During the time of apartheid in South Africa, students on college campuses were very active in the campaign to divest from South African companies (Gallagher, 2013). Students, especially active and involved students like those at Clark, can be very passionate and believe their school should feel obligated to address current global and political issues. Fossil fuel divestment has gained a growing base on over three hundred college campuses because of these passionate reactions (Gallagher, 2013). Some colleges, including Unity and Hampshire College, have made commitments to divest along with many other institutions (Gallagher, 2013). College campuses are not the only institutions divesting; many religious organizations and state governments are also being pressured to divest (Fossil Free, 2013).

Successful divestment at Clark University would demonstrate to a larger community that Clark does not support the way that fossil fuel companies are profiting from harming the environment (Fossil Free, 2013).

Colleges and universities, as well as cities and religious institutions are choosing to divest from fossil fuel companies and discontinue supporting our reliance on fossil fuels (Fossil Free, 2013). Organizations have a choice in how they invest their resources; they can continue to invest in these companies or switch to other more environmentally friendly, non-fossil fuel based companies. The most recent college that has committed to divest is Yale University (Shelton, 2013).

The Aperio Group recently found that divestment from fossil fuels would not increase risk to an unacceptable level (Gardner, 2013). Our team spent this semester researching the challenges, risks, and opportunities that could come with fossil-fuel divestment at Clark University. Our strategy was to contact schools with successful divestment campaigns, research fossil fuel divestment generally, contact Clark University's financial officers to obtain Clark's investments, learn more about the financial structure of a university and assess the risks and benefits of potential divestment at Clark University.

Background

Fossil fuels and climate change have become critical political and social issues. Investments in fossil fuels are both lucrative and stable investments for institutions but could also be considered politically controversial.

The threat of global climate change is one that has become more of a public concern over time. The prospect of divesting from fossil fuels is significant and progressive. Management of a university's endowment is also central to the institution; endowments enable the institution to prosper and fund important aspects of the university. Large changes in university finance are often resisted, especially when the reason for the change is one that does not necessarily have immediately tangible benefits - like fossil fuel divestment.

The Intergovernmental Panel on Climate Change recently released the Summary for Policy Makers that included data about climate change and how it is greatly changing our environments (IPCC, 2013). One finding illustrated that the world is experiencing great melting of ice in the arctic (IPCC, 2013). The presence of ice sheets is significant for many reasons, but most importantly, they absorb the sunlight that would otherwise be hitting the Earth's surface and warming it

(Plummer, 2012). Other findings from the IPCC were that the rising sea level is also a risk and that carbon dioxide is present at higher concentrations in our atmosphere than it has been in the last 800,000 years (IPCC, 2013).

Transitioning away from fossil fuels is one concrete change that could reduce these climate risks. Fossil fuel divestment does not resemble recycling or carpooling in that it does not directly reduce usage of resources. Fossil fuel divestment modifies the inner workings of our institutions, and demonstrates financial pressure for change. This modification makes a statement that the world should move away from using fossil-based, nonrenewable resources (oil, coal and gas) that create cheap energy and exponential environmental degradation.

These ideas are not new to the campus of Clark University. Clark is a highly aware, politically involved campus that is deeply engaged in environmental concerns. Clark University's mission statement says that "Clark University's mission is to educate undergraduate and graduate students to be imaginative and contributing citizens of the world, and to advance the frontiers of knowledge and understanding…" (Clark University, 2013). By saying "contributing citizens of the world", Clark University infers that true understanding includes viewing the world globally (Clark University, 2013). Climate change is a global challenge that we all must engage in and attempt to help stop.

Clark's mission statement also includes "Clark contributes to understanding human development, assessing relationships between people and the environment, and managing risk in a technological society" (Clark University, 2013). The challenge of climate change is centered on the relationships between people, their environment and how society manages risk. Therefore, considering responses to climate change and other environmental concerns is clearly a critical part of Clark University's mission.

By all accounts, the campus of Clark University does have a sustainable mindset. We have a Climate Action Plan that is attempting to reach climate neutrality (Clark University Climate Action Plan, 2013). There are two goals to this plan: (1) reduce emissions by 20% from 2005 levels by 2015, and (2) achieve net zero greenhouse gas emissions by 2030 (Clark University Climate Action Plan, 2013).

At Clark University, we also compost our food waste, put a big emphasis on recycling, use high efficiency washers and dryers in our residence halls, have a cogeneration plant on campus, and teach classes like the Sustainable University that push for even more greening initiatives on our campus.

Clark University has not, however, taken the additional step of divesting from fossil fuels. Divesting from fossil fuels does not reduce campus resource usage of nonrenewable resources or have a direct influence on the environmental impact of the campus. But it does push the world away from fossil fuels and encourages investment in more environmentally responsible companies (Humphreys, 2013).

Other students here at Clark had already begun work on fossil fuel divestment before we began our project. One student, Savannah Cooley, started a modest petition and began an effort to get Clark's investment information during the 2012-2013 academic year (Cooley, Savannah. Personal Communication). Other students in Clark's graduate school, Chris Davies and Robin Miller, considered the

movement and were looking for a place to begin (Davies, Christian. Miller, Robin. Personal Communication). Worcester Polytechnic Institute also has a divestment campaign that is still working to get word to students and procure their University's finances (Pollin, Ryan. Personal Communication).

Our team understands and discovered that fossil fuel divestment is a daunting shift in not only a university's finances but also in how the university thinks about what it chooses to invest in. We also understand that the benefits of divesting are largely intangible and potentially more symbolic than the everyday efforts the university is already committed to in reaching for a more sustainable future. Fossil fuel divestment is also something that needs to be well justified and quantified in order to be considered by a university, including Clark.

Process

Our research involved communicating with many people both within and outside of Clark University as well as researching to learn about the growing fossil-fuel divestment movement. Communication involved face to face meetings, phone calls, and emails. Our research also involved learning about schools that had successful campaigns. We also contacted Clark's Social Responsibility Trustee Committee to obtain more detailed information about Clark's investments.

One of our early steps in this process was attending a fossil-fuel divestment meeting at Worcester Polytechnic Institute. WPI had started a divestment campaign but had recently received a letter from the WPI President informing the group that WPI was not going to consider divestment (Pollin, Ryan. Personal Communication). This meeting was helpful because it provided us with an opportunity to ask any questions that we thought would benefit us in understanding the many challenges and opportunities involved in divestment. Representatives of the WPI divestment campaign told us that their campaign hit a roadblock the past year when the administration sent out a letter saying that fossil fuel divestment was not an option at WPI (Pollin, Ryan. Personal Communication). Another challenge students at WPI encountered was the refusal of the college to disclose information about the university's investments (Pollin, Ryan. Personal Communication).

In addition to attending this meeting and emailing schools and individuals to find characteristics of successful divestment campaigns, we also contacted Julie Dolan, the newly selected Executive Vice President and Treasurer of Clark University. Julie Dolan, as soon as she fully takes over her new position, will be responsible for Clark's investments. While Julie is adjusting to her new position, Jim Collins, the previous administrator responsible for overlooking Clark's investments, is managing the investments to assist in easing her transition. Upon meeting with both Julie Dolan and Jim Collins, we received information about the companies that Clark University invests in. Jim Collins and Julie Dolan informed us that Clark only has access to the companies that make up twenty percent of Clark's total endowment (Dolan, Julie. Personal Communication). Clark University uses fund managers to invest its endowment and signs non-disclosure agreements with these fund managers (Collins, Jim and Dolan, Julie. Personal Communication). This means that students, administrators and the rest of the campus community have no way of

knowing where 80% of the endowment is invested at any given moment (Collins, Jim and Dolan, Julie. Personal Communication).

Results

Fossil fuel divestment, for many reasons, is not an easy idea to implement or define. Despite the fact that fossil fuel divestment is a growing movement that is gaining momentum, there are multiple issues and questions that still have to be answered before any institution, including Clark University, can proceed to divest.

The first and most difficult issue we ran into was actually defining fossil fuel divestment. Because Fossil Free defines divestment only by fossil fuel reserves in the ground (Fossil Free, 2013), organizations that have "divested" by Fossil Free's definition can still hold stock in companies that do things like lease oil rigs, drill oil, manufacture oil technology, or assist in the production of oil including oil refining. Many individuals and organizations seeking divestment could be concerned or unhappy with this definition because divestment as defined by Fossil Free, could still include other companies that profit from oil production and drilling. Fossil Free's definition, however, seems to be the most widely accepted definition within the fossil fuel divestment movement; although it is not perfect, it provides consistent limits. We found that there is no one universal definition that is accepted or even applicable to all schools.

How to define and where to draw the line in fossil fuel divestment is a big question that also came up in our meeting with Julie Dolan and Jim Collins. Julie Dolan asked us if fossil fuel divestment would also include divesting from companies like General Motors that make products that use fossil fuels.

In the entire divestment movement there is also the question of if divesting is even a reasonable solution because each and every day, we all use fossil fuels in one form or another. This happened to be one of the many arguments that was made in a letter that the President of Harvard University, Drew Faust, wrote in October 2013 in response to the growing presence of a divestment campaign on the Harvard campus (Faust, 2013).

> *"I also find a troubling inconsistency in the notion that, as an investor, we should boycott a whole class of companies at the same time that, as individuals and as a community, we are extensively relying on those companies' products and services for so much of what we do every day. Given our pervasive dependence on these companies for the energy to heat and light our buildings, to fuel our transportation, and to run our computers and appliances, it is hard for me to reconcile that reliance with a refusal to countenance any relationship with these companies through our investments" (Faust, 2013).*

Investments are at the financial core of a university. Without the funds that can come from investments, the university is limited in its ability to offer new programs, hire new staff members, fund student activities, offer financial aid, build new buildings, expand departments and grow as an institution. Any proposed change to how a university invests its money is one that needs to be seriously considered because of its potential consequences. One of the main concerns of

investors is the risk that could be involved in fossil fuel divestment (Humphreys, 2013). Our research led us to various sources of information on financial risk management, but we were also unable to quantify this risk directly because of our lack of experience dealing with investments and lack of knowledge about Clark's specific investments. We came across several sources that claimed that divesting from fossil fuels does not increase risk (Gardner, 2013), but we could not evaluate the potential risk involved in divestment at Clark because of our lack of experience and knowledge of Clark's investments. We recognize that for divestment to move forward, advocates would have to justify to the Clark Board of Trustees specifically why divesting at Clark University does not increase risk and what benefits it could bring.

There is also the issue of more social connections between a university and a fossil fuel company. Worcester Polytechnic Institute experienced this problem firsthand (Pollin, Ryan. Personal Communication). WPI recently had the CEO of Exxon Mobil as a speaker at their graduation ceremonies and has an Exxon Mobil executive on their board of trustees (Pollin, Ryan. Personal Communication). WPI serves as an example that there could also be additional complicated, unspoken social consequences to divestment.

An issue that we ran into here at Clark was that in order for the university to take action, there needs to be a solid justification and buy-in at the highest levels of the University administration. Last year a student approached President David Angel about the possibility of divestment; this student was told that the harm to the environment and benefits of potentially divesting needed to be quantified in something like a cost-benefit analysis that was very black and white, apolitical and financially specific (Cooley, Savannah. Personal Communication). Due to the constraints of time and experience, our team was unable to provide a formal analysis of Clark University's finances to justify divestment.

An institution like Clark with green initiatives and sustainable motivation may not necessarily want to invest in fossil fuels. These universities are aware of the impacts of global climate change and fossil fuels just as their students are. But they are also aware that they cannot take unnecessary risk in their university's finances. Before taking action in any direction, universities need a clear justification for what they are doing and what impacts, both positive and negative, are anticipated. Based on our research, our team found that fossil fuel divestment definitely has some appealing qualities; it sounds like a good idea and a potentially powerful way for a university to make a statement about it's societal priorities. Fossil fuel divestment, however, is a process that needs strong justification and quantitative analysis in order to be carried out.

Discussion and Conclusions

After working on this project for the semester, we have discovered that change within an institution moves slowly and requires heavy justification. We received our University's finances and considered what could be done with the information available and the information that is not accessible.

The challenges of non-disclosure agreements in regards to financial information were the biggest roadblocks for our project. Not knowing exactly what

fossil fuel companies Clark invests in and the size of these investments results in an element of the unknown to a movement that needs clarity and transparency. Fossil fuel divestment itself also has many roadblocks that are much more difficult to overcome, such as university politics, campus-wide support, and finding reinvestment options with similar return on investments and less or equal risk.

Fossil fuel divestment will not be achieved at Clark until the University can firmly define what divestment means to Clark and be able to quantitatively justify it. Divestment has many good logical and political arguments, but those arguments are not the first priority of our trustees; their responsibility is to keep our university safely funded.

In the given time frame, our group was unable to justify divestment. We found many of the compelling political and social arguments, but we were unable to assess what the financial risks of divestment would be for Clark University. Until that can be achieved, we find it difficult to advocate for or against divestment.

Recommendations

Because of the complicated nature of this project, we have several recommendations to give to anyone who plans to work on this project at Clark University or another institution. The first is to be patient. Change and even information gathering within an institution can be slow as we experienced. It is also important to approach people within these institutions with a pleasant disposition. Both Julie Dolan and Jim Collins were very pleasant and helpful when we met with them. They wanted to help us understand the financial structure of our university and they asked questions about our project too. In our experience, trustees and administrators in an institution are open to discussing almost anything; they are interested in students' ideas, but it is also helpful to be prepared when meeting with administration.

It would also be beneficial to involve increasing student awareness. Having a few students who feel very strongly about divestment is a good place to start. But having a few dozen or a few hundred students feel strongly about something will place more pressure on the institution to respond to what those students feel so passionate about.

Another recommendation is to expect roadblocks. This project had many changes and twists and turns. We were left with many unanswered questions and unresolved problems at the end of the semester. A concrete recommendation for the continuation of this specific project is to quantify the benefits and risks of divestment in some way. Clark University knows that climate change is a negative for our planet, but the Clark also has to explore as a whole whether or not divestment is viable and justifiable. Institutions, students across the country, and even President Obama know that divestment is an important movement, but we have learned that any arguments for divestment must be balanced with strong, apolitical justification.

Index of Key Contacts

- Jim Collins - Vice President for Administration and Finance at Clark University
- Savannah Cooley - Clark University Undergraduate
- Christian Davies - Environmental Science & Policy/MBA Dual Degree Graduate Student at Clark University.
- Randy Rice- Trillium Asset Management
- Phyllis Duff - Worcester State and The 350.org Representative for Worcester
- Ryan Pollin- Student at WPI, Member of WPI's Students for a Just and Sustainable Future
- Julie Dolan - Executive Vice President of Clark University
- Robin Miller - Environmental Sciene & Policy/MBA Dual Degree Graduate Student at Clark University.
- Ed Ottensmeyer - Clark University Associate Professor of Management

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Severe Storm Preparedness at Clark University

Thor Akerley, Olivia Cecchi, Zac Peloquin

Abstract

The following paper seeks to assess and evaluate four specific systems of Clark University under the pressure of severe weather. Although Clark University already has a strong climate mitigation program, increasing threats of severe weather are creating a need for adaptation efforts as well. This paper will identify vulnerabilities of the Clark's food systems, water systems, communication systems, and evacuation plans, while providing future considerations for the University to build upon and strengthen these systems. In addition, we will provide examples of preparation at other schools, in the hopes that this will help Clark develop more comprehensible severe storm preparedness plans for the University.

Introduction

Human induced climate change has created numerous challenges for our society. One of those problems is finding a way to deal with a predicted and observed increase in severe storms and storm severity. Global warming accelerates the hydrologic cycle by evaporating more water, transporting that water vapor to higher latitudes, and producing more intense and possibly more frequent storms (Emanuel 1987, Walsh and Pittock 1998). Even if the frequency does not increase, it is likely that intensity and possibly duration of individual storms will increase because of the warming of the air and ocean, sources of energy for a hurricane (Emanuel 1987, Walsh and Pittock 1998). Due to the exacerbation of the hydrological cycle, heavy rainfall events are expected to become more frequent and more severe according to other sources. Heavy downpours that are now 1-in-20-year occurrences are projected to occur about every 4 to 15 years by the end of this century, depending on location, and the intensity of heavy downpours is also expected to increase (globalchange.gov, 2009). The 1-in-20-year heavy downpour is expected to be between 10 and 25 percent heavier by the end of the century than it is now (Kunkel et al, 2008). This is of particular interest because increases in storm severity and longevity have the potential to increase flooding, which is of particular interest in an urban setting. Future climate scenarios show likely increases in the frequency of extreme precipitation events, including precipitation during hurricanes, raising the risk of floods too (Greenough et al. 2001).

Severe storms have the potential to be extremely harmful to human health. Extreme weather events such as precipitation extremes and severe storms cause hundreds of deaths and injuries annually in the United States (Greenough et al. 2001). As if human health isn't reason enough to make sure we are prepared for severe storms, there is the economic incentive as well. Hurricane Sandy was the most recent super storm, which made landfall into the New Jersey and New York coastlines last fall (2012), with U.S. damage estimates near $50 billion, making it the second-costliest cyclone to hit the United States since 1900, according to the NHC (Sharp, 2012). The cost of weather related losses have increased dramatically since 1980. For example, during the time period covered in the figure below (figure 1, globalchange.gov, 2009) population increased by a factor of 1.3 while losses increased by a factor of 15 to 20 in inflation-corrected dollars (globalchange.gov, 2009).

With an increase in more severe and potentially more disastrous storms headed our way it is our responsibility to adapt to protect students who are housed at Clark University in the case of an emergency. At the 2013 Humanitarian Action Summit: Climate and Crisis, Climate scientists and disaster relief workers wrapped up a meeting in agreement about the importance of leveraging climate insights into improved disaster preparedness as the planet warms (Powell, 2013). Our project will aim to support the current efforts Clark has ongoing to prepare for severe storms, and to provide additional insight and research in current vulnerabilities. Whether or not increased health risks due to climate change are realized will depend largely on societal responses and underlying vulnerability (globalchange.gov, 2009). Our role is to assess Clark's current facilities (Water, Food, Communication, and Shelter) during an extreme weather event and helps move the ball forwards in becoming a more resilient University in the face of Climate Change. We chose to focus on these aspects because they were all mentioned in our interviews with Clark administration and officials. They by no means cover all the necessary preparations needed for a severe weather event. We hope that by focusing on these few key facilities will keep the ball moving forwards in terms of recognizing climate change preparedness and resiliency as a major topic of research and development moving forward.

That sentiment is being further recognized in today's society at both a national scale, and on a small scale, institutional level. The role of adaptation to climate change and variability is increasingly considered in academic research, and its significance is being recognized in national and international policy debates on climate change (Smit et al., 1998). These changes in international and national policy are changing the landscape of institutions, even ones like Universities. Emergency response plans are not new to Universities, and neither are weather response plans, however climate change adaptation and preparing by improved resiliency are new fields that are rapidly expanding at the University level. Progressively minded schools like Clark University are one of the many institutions working to improve their resilience and preparedness for climate change and increasingly severe weather in today's society.

Background

Clark University is a liberal arts college located in Worcester, Massachusetts. Currently there are 2,277 undergraduate, and 1087 graduate students enrolled at the University. Over the last three years, Clark has experienced storms like Hurricane Irene, Super-storm Sandy, and Nor'easter Nemo. Although the school thankfully received minimal damages, these instances of severe weather devastated many surrounding areas in the northeast. Clark recognizes that climate change plays a crucial role in the recent changes in weather patterns over the years. In 2009, Clark released their Climate Action Plan, which detailed mitigation strategies for the University to reduce its greenhouse emissions to net zero, or no emission, by the year 2030. As of 2012, Clark was on track to meet this goal (Clark University Greenhouse Gas Emissions Update: 2012, 2012). In addition, in 2007 Clark signed the American College and University Presidents Climate Commitment, a pledge to reduce emissions and reach climate neutrality (Second Nature, 2013).

However, the Climate Action Plan, and the American College and University Presidents Climate Commitment simply focus on mitigation of climate issues. Although these systems hope to reduce the some of the factors that lead to the creation of extreme

weather, these plans do little to address climate preparedness at Clark. Climate Preparedness is seen as actions that can be undertaken to reduce a company or institution's vulnerability to climate change hazards (Boston Green Ribbon Commission, 2013). Although Clark has several plans that deal with emergency situations, there is virtually no mention of climate preparedness within these documents. Currently Clark has four emergency preparation documents including: Clark University Emergency Response Plan, Active Shooter Emergency Plan, Hurricane Preparedness Plan, and the Water Outage Preparedness Plan. Out of these four plans, three were updated in the spring of 2013, with the exception of the Emergency Response Plan (Clark University Emergency Response Plan, 2011). As severe storms become ever more present, it is important for Clark University to not only implement plans of climate preparedness, but also evaluate and strengthen the current systems in place.

Process

In the beginning the Team was assigned the topic Climate Preparedness on Campus. Through a process of weekly meetings between team members it was decided to focus on severe weather preparedness. This processes that included both meetings and back and forth email communications with various members of the Emergency Response Team, Professor Jennie Stephen, Peer Learning Assistant Sharon Bort, and Sustainability Coordinator Jenny Isler. The process of researching Clark's current plans and documents in regards to Emergency Response Plans and Climate Action Plans. There was also consideration given to what could actually be accomplished in only one semester. Based upon the feedback given and upon the time restraints it was determined that the most achievable goal was an overall assessment and statement of the practice already in place. The team decided to focus on several critical services that could come under threat during a severe storm. The team decided to focus water, food, communication, and shelter. With food services there was an assessment of what policies are in place to ensure that there is enough food during a severe storm, food security during the storm, and preparation in advance of an approaching storm. Communication consists of evaluating current communication methods, evaluating ways of improvements, assessing enrollment in communication methods, and methods of improvement. Water was assessed in regards to security of supply, amount of the supply, and how the supply is distributed throughout the duration of a severe storm. Shelter is assessment consists of identifying the evacuation locations, determining which were the preferred, the decision on which students would be evacuated, as well as what would happen should it be necessary to evacuate the entire campus for safety reason. These are but a few of the services that could come under threat during a severe storm. There are comparisons to other schools and recommendations as to how Clark could improve the preparedness/ effectiveness of the current policies.

Results and Discussions

Food Security During a Severe Storm

Current Status

Clark is responsible for proving to about 1700 students at meals throughout the day because there are approximately 1780 students currently on the meal plan. Typically, dining service serves 400 people during breakfast, 850-1150 at lunch, and 900-1200 at

dinner. We receive fresh produce 6 days per week, milk 3 days per week, large distributor (Sysco) 3 days per week and bread 6 days per week. All of the trucks are large box trucks except Sysco. That food is delivered in a dual degree tractor-trailer truck. Our food doesn't take up the whole truck but is typically 6 pallets of food and paper goods (Heather Vaillette, General Manager of Dining Services). During a severe event, this changes though.

The amount we would stock would depend on the type of storm and severity. However, we would plan on 3 days worth of food without any impact on options. We would have 5 days worth of food for severe storms that could cause delivery issues such several feet of snow and possible power outages. Perishables would be kept to a minimum and would be prepared items such as presliced meats/cheese and whole fruit rather than uncut meat that would require electrical appliances. We would order higher amounts of bread and canned goods in case we lose power for longer periods. Our walk in refrigerators are on generators so it would be extremely unlikely to lose the basic goods we have (Heather Vaillette).

During a severe storm where the dining hall would be forced to close (this has happened during a few past major snow storms), dining services would provide students with bagged lunches. To be exact, dining services will make 2,000 bagged lunches per meal, to ensure that students on campus who are not on the meal plan will have access to food as well.

While discussing the topic of vulnerability and severe storms with Heather, we also gathered that dining services is extremely flexible in their mission to feed students. She mentioned that dining services staff has the ability to stay overnight on the Clark campus if a major storm may threaten driving the next day to ensure students get fed. Furthermore, if students were ever evacuated outside their dorms or were not allowed to leave their dorms dining services would supposedly be able to move their operation to a secondary location and act as a new hub for food, ideally closer to the students new location. This further exemplifies why Clark is so prepared for a severe storm, and why this is one area that Clark may not need to focus on when improving it's climate preparedness and resiliency.

Food Assessment and Comparison to Other Schools

Through talking with dining services general manager, Heather Vaillette it is clear that weather preparedness is one of the most important pieces of all of dining services. After all, if we (Clark) couldn't feed our students during a time of need, what could we do? Clark is an example of a school that is clearly extremely prepared for events such as heavy snowstorms and torrential downpours. Being able to stock up on enough food to feed all of its students (and then some) for a week is more than enough food, barring an absolute destruction of Worcester or Clark. Dining services flexibility is also key in the event of severe weather. Being able to relocate to a location closer to students' locations could be vital to getting students enough food.

However, there a couple things that dining services could think about when considering severe storm preparedness. First, all of their food is kept in a central location (the basement of the University Center), which is potentially vulnerable to flooding. Incorporating a second location for food storage could prove beneficial in the long run, if a major storm were ever to threaten food storage. Secondly, the limited nature of perishable foods may be difficult for some students who are gluten intolerant, have other

food restrictions, and people in general. This comes back to my first point in that maybe dining services could consider a second location for food storage that also had extra refrigeration that would be stocked only for severe weather events just in case.

While it would also be valuable to include comparisons and improvements to food security from other Universities, this kind of research and preparedness is relatively new and most of this kind of information is in the planning, and not publishing stage. Information on other schools practices of food security during severe storms is non-existent on the Internet. This doesn't mean this type of work is not important, but rather that it is a budding area of research and deployment at the University level.

Water Security during a Severe Storm

Current Status:

It is estimated that a person can survive up to three weeks without food, but only about 10 days without water (Live Science, 2013). Within the last three years Clark has faced threats such as Hurricane Irene, Super-storm Sandy, nor'easter Nemo. Although, thankfully during these instances Clark incurred minimal damage, these occurrences devastated many areas geographically close to Clark. This section of the paper will assess Clark's water security, and how water systems through Clark could be affected by threatening weather. We will compare Clark's strengths and weaknesses when it comes to water vulnerability on campus. We will also examine the practices of other universities, in efforts to encourage improvement in areas that Clark is particularly susceptible.

As of January 11, 2013 Clark has updated Water Outage Preparedness and Response Plan (WOPRP). The WOPRP, like many of Clark's other emergency response plan is simply a guideline for both faculty, staff, and students throughout Clark during times of water outage. The WOPRP defines, outlines, and delegate's processes to overcome and minimize the hazards associated with water outage on Clark's campus. The Emergency Response team recognizes that each situation in which there is water outage can be very different, so the WOPRP serves as a basic outline, which can be built upon depending on the situation. The WOPRP lays out the responsibilities of different systems within Clark, for example: Physical Plant is responsible for acquiring portable toilets, Dining Services will review menu items and formulate a plan for continuity of dining operations, and Residential Life and Housing will assist in relocating any displaced students (Water Outage Preparedness Plan, 2013). These are just a few of the responsibilities laid out by the response plan, however it is evident that Clark has given quite some thought in preparing for water outages.

In terms of providing potable water to students during an event of severe weather, we decided to examine the preparedness of Clark's Dining Services. We were fortunate enough to work with Heather Valliette the General Manager of Clark's Dining Services in order to learn more about the vulnerabilities and strengths of Clark's current water security. With about 1780 Clark students on the meal plan, Dining Services utilizes about 250 gallons of water a day for both student beverage consumption and food production. When the water is shut down, Mrs. Valliette explained that several means of food production are shut down in order to conserve water and preserve certain machines. Fountain beverages, and coffee are shut down in the cafeteria and bistro, but are replaced with independent Poland Spring water stations. Employee hand washing stations also go

down, however large insulated cambros are filled with hot water in order to keep food production sanitary during the time of the shutdown. The dish machine is inoperable without water, so the cafeteria switches to paper plates and plastic utensils. Mrs. Valliette informed us that dining services stores a minimum 250 gallons of water available for immediate use always on hand. There is always also an emergency backup supply of 200 gallons in 5-gallon tubs, and 50 cases of bottled water.

Clark's current water preparation seems to be very well prepared for short run occurrences. In the last year Clark has experienced two water main breaks that have affected Clark's access to water, therefore this familiarity has strengthened Clark's preparedness for these situations. Although these seem to be very temporary solutions to lack of potable water, Mrs. Valliette was confident that Sodexo suppliers in the area would be able to supply more water should the need persist for a longer period of time.

Future Considerations & Comparison to other Schools

Although Clark seems to have a pretty good handle on water security, as extreme weather becomes an increasingly larger threat it is important to prepare for long-term damages and water outages. Even though Clark has about a two days worth of water stored in total, this could prove to be difficult if there is extreme damage to the water system because of a storm. It should be encouraged for Clark to store a greater amount of bottled or 5-gallon jugs of water for long-term distribution. Furthermore, the WOPRP is a plan put into action just before, or after water has been shut off on campus. Creating a more preemptive plan for water security, could allow for more safety and preparedness in the future. Lastly, several Clark authorities we talked to mentioned the aging Worcester pipe system as a vulnerability under the threat of an extreme storm. As mentioned before, Clark has experienced two water main breaks in the last year that lead to the shutdown of water on campus. Because Clark already plays such a proactive role in the Main South and Worcester Community, we would suggest and encourage future collaboration between the institution and the city in order to improve and strengthen the Worcester pipe system ultimately providing better water security not only for Clark, but for the surrounding neighborhoods as well.

In terms of the preparation of other schools in the face of water insecurity, it was hard to find precise or accurate numbers in regards to school's preparedness. However we were able to find several schools with overall "Emergency Plans" that highlighted the role of students in the process of climate preparation. Texas A&M has something called the Extension Disaster Education Network, a website that listed several disaster preparedness resources for individuals, families, college students, youth, and other specific populations. For the college student resource, Texas A&M suggested that students should develop an emergency action plan, as well as create a disaster supply kit. They instructed that these kits be filled with a three day supply of water, or 1 gallon per person per day. They also recommended storing water purification tablets to be used should water supply run out (Texas A&M, 2013). The College of Southern Maryland had a similar website that offered resources for students to create their own emergency plans and supply kits. The College of Southern Maryland's website was informative, breaking down how to prepare for different types of disasters like Hurricanes or Earthquakes. This website too encouraged students to store three to five days worth of water in case of an emergency situation (College of Southern Maryland, 2013). Both schools utilized their websites to create a platform for students to prepare their own

emergency action plans, and emergency kits. Implementing something similar to this at Clark could prove to be very beneficial to the safety of the entire campus when faced with extreme weather. Not only would these kits be helpful to the students, but by having students store their own water, this would remove some burden off of Dining Services. Therefore if they were for some reason unable to get more water trucked into Clark, students would already have their own supply.

Emergency Communication and Notification

Current Status:

Clark currently has an entire emergency notification plan in place, which I received from Clark's business manager, Paul Wykes. The goal of the plan is to serve as the primary tool for communications related to safety and crisis situations, including communication within the Clark community. It has been developed to provide guidance to University officials in regards to delivering an effective, efficient, timely and comprehensive message before, during, and after emergency situations (Clarks Safety and Emergency Communications Plan). Currently, 50% of the students, faculty, and staff are enrolled in the Clark Alert's text program, where those enrolled would receive a text and email regarding the current emergency. A severe storm threatening some of Clark's key facilities (Water, Food, Shelter) falls under this category according to the Emergency Communication Plan. Clark also has the ability to leave voice messages to those who have provided phone numbers to the Clark Alerts program.

Emergency Communication Assessment and School Comparison

Clark University and the members of the emergency preparedness taskforce has undoubtedly worked incredibly hard in crafting a well thought-out and thorough plan to have stable communications during a stressful and dire times. That being said, Clark Alerts is a great program that may very well be the quickest option of reaching students, staff, and faculty at a moments notice. Relying on emails for a moments notice notification is most likely not the most effective way of informing campus residents. Based on this, Clark's current Clark Alerts enrollment of 50% is a major risk for those living on the Clark campus. Chief Stephen Goulet even said that it would be extraordinarily helpful if we could get that number up. For example, if 50% of campus residents didn't know that they were supposed to evacuate, or relocate somewhere immediately there are serious liability and danger risks for both the University and students. This also applies to non-weather situations such as an active shooter.

Due to the unpredictable and potentially disastrous nature of weather we found that improving Clark's student, faculty, and staff enrollment in the Clark Alerts program is vital to improving emergency response times within the Clark community. While Clark doesn't incorporate visual or voice emergency notification system into their emergency plan, it makes the higher enrollment in the Clark Alerts program even more crucial.

Other schools, such as Yale, who have about five times the students Clark does incorporate PA (Public Address) systems into some of their buildings (Emergency Management at Yale). Currently, only the Goddard library has any type of PA system installed. It's possible Clark could explore something similar to this in their dorms as well as other major buildings around campus such as Jefferson, Jonas Clark, and the UC.

Because Clark is even smaller than Yale, it should be easier and less expensive to incorporate this type of system into their dorms and key campus buildings.

Emergency Shelter Evaluation

Current Status:

There are multiple locations on campus that have been consider as sheltering spots for students during a severe storm. Upon consulting with various members of members of the Clark Emergency Response Team (Chief of University Police Goulet and Director of Physical Plant Michael Dawley). These two contacts have listed their preference and reasoning for why certain buildings are prioritized over others as evacuation locations. This document is to assess the characteristics of each to buildings that can be used to house student in a severe storm. The buildings are listed primarily in the order that Chief Goulet and Director Dawley indicated that they would wish to evacuate students to if it were necessary for student safety.

First Choice: Students Shelter in Place

Students remaining in their dorms was the first choice of all parties consulted when it came to shelter for a severe storm. This would cause the least disturbance to the student body and will allow the Emergency Response Team to focus on the task of preparing for the storm instead of moving students. Certain dorms have characteristics that could aid or harm them in a severe storm. Dana and Hughes Halls do not have large windows in the common areas that can be broken by projectiles in a storm. There is then less of a chance of students being hurt by breaking glass. Johnson-Stanford, Bullock, Blackstone, and Wright Hall all have common areas with large floor to ceiling windows that can be broken or damaged by projectiles in storm. Projectiles are perhaps the greatest threat to the large windows of the residence halls. These projectiles can suddenly break a window and cause shards of glass to go into the common room and injure students that are in there at the time. Keeping students in multiple locations can be beneficial as if an event occurs and damages one dorm there are fewer students that can be injured or killed. However with students in multiple locations can strain on the Response Team's resources by forcing the Team to have to focus on protecting multiple locations. This division could hinder the Team's ability to respond to an incident occurring at a certain location.

If students can safely remain in their dorms this would be the most desirable choice for the members of the Emergency Response Team that were consulted. The reasoning is that there would be less stressful for the students and it would also free of Emergency resources for other tasks. The weakness of keeping students in their dorms is that if evacuation becomes necessary than students must be moved in the middle of a severe storm. If students shelter in their dorms there are several questions that should be considered. During the storm what should students do if there is no access to washers, dryers, and showers in the dorms? Additionally, in the event of the common room windows breaking there are several possibilities that must be considered. Does the Emergency Response Team evacuate students from the entire dorm, just the effect floor, or simply bar students from entering the common room of the affected floor?

Second Choice: Kneller Athletic Center and Dolan Field House:

The Kneller Athletic Center occupies approximately 69,000 square feet. This is based off of the old Kneller Center before the renovation of the Bickman Fitness Center.

There is no separation indicated between the Kneller Center and the Bickman Fitness Center. The square footage of all the buildings on Clark campus in this assessment was obtained from Physical Plant records. These records were provided at the request of the Shelter Assessment Team Member. The Dolan Field House occupies approximately 31,500 square feet (Clark Physical Plant Maintenance Records). These athletic centers would be the first two choices of shelters should it be necessary to evacuate students from the dorms. Their combined square footage occupies approximately 100,500 ft. The combined square footage for all of the residence halls is approximately 335,200 ft. which would house approximately 1,422 students. (Email Correspondences with the Director of Housing Kevin Forti). The combined square footage of residence houses and Clark owned apartments, is 110,800 ft. which house approximately 230 students. (Email Correspondences with the Director of Housing Kevin Forti). The number of students in Clark Housing is the combined number of students in both forms of Clark housing approximately 1,600 however these numbers tend to fluctuate and should be considered approximate numbers. The total enrollment at Clark is approximately 3,100 students. This means that only a little over half of enrolled students are housed in Clark owned buildings.A major question is how to differentiate between students that live in off-campus apartments and how many commute to classes. When consulted Kevin Forti stated that he was unsure of how many students live off-campus.

There is also major difference in the combined square footage of the dorms and residence house and the combined square footage of the Kneller and the Dolan. This leads to the question whether the evacuation shelters can actually house even all of the student's currently living on-campus. There was a difference of opinion when it came to sheltering off-campus students in the evacuation location. Director Dawley was of the opinion that it was not the responsibility of the University to provide shelter to students that had chosen to live off-campus. His argument was that the students that are living off-campus have made the conscious choice to live off campus. They are adults and are capable of preparing for an emergency situation. With regard to the Emergency Response Plan, it is the Dean of Students that would be in charge of making arrangements for both on campus and off campus students. What is stated in the Emergency Response Plan is that the Dean of students will "coordinate with local agencies and support organizations to provide shelter alternatives for off campus students".(Emergency Response Plan Page 9) Chief Goulet, on the other hand, suggested finding some way to include off-campus students directly into Clark's emergency response instead of sending them to local agencies. His preference was for finding a way to include off-campus student in any sort of evacuation order. This is a serious difference between two major members of the Emergency Response Team, which could cause major issues should a situation in which students needed to be evacuated or relocated present itself in the future.

A hazard to the Kneller is that there are several very tall trees that could damage the Kneller during a severe storm either before or after students have been evacuated to it. If these trees were to be toppled during a storm onto the Kneller they could cripple the one major shelter that Clark has. If the one major shelter on campus were compromised there is not another building large enough that was considered to be large enough to shelter the on-campus student body. The Dolan, while considered as a shelter, was not thought of as a primary shelter. It was thought of mostly as an overflow shelter should the Kneller be come to crowded. There seemed to be little concern about how comfortable

the stay would be for students in the Kneller. Director Dawley was a strong advocate of using the Kneller as the only shelter as it would allow all the students to be housed in one primary location that was easy to access. Chief Goulet was less supportive of placing the all of the on-campus students in one place. He raised concerns of what would happen if the Kneller was compromised while all students were sheltering in it.

The Kneller Athletic Center was the first choice of Director Dawley if evacuation became necessary. Chief Goulet noted concerns about the integrity of the roof of the Kneller Center as a concern when considering to evacuating students to it. However when these concerns were raised with Director Dawley, he gave assurances that the roof was safe enough that he felt confident about putting students in the building. There is always the concern if the winds get strong enough that the roof can damage. The greatest concern is what will happen if the Kneller if compromised while students are in it. If the primary evacuation location is compromised where students would be relocated to next? In the event that evacuation from a dorm became necessary the Emergency Response Team would evacuate students from the damaged dorm to the Kneller. The Kneller Center is in a central location that will allow students easy access to the building. The Kneller could be used in the event of the loss of power/water/ damage to one of the dorms.

Another question that was not fully answered by the Emergency Response Team members was whether students that are physically live closer to the Dolan Field House would be evacuated to it. If students that were closer to the Dolan were evacuated to it, there would be less stress placed on the Kneller systems, sewer, water, and overall space. However this would force the Emergency Response Team to focus on protecting two locations that are on opposite ends of the Campus. This could strain the resources of the team and hamper their abilities to respond to an incident occurring at one of the location. There is also the consideration that the roads between the two facilities may become too hazardous to travel, effectively cutting the facilities off from one another. A benefit of keeping the student population dispersed in various locations is that if something does happen at one location there is a chance of fewer students being injured or killed.

Goddard Library and Academic Commons

The Goddard Library, the largest Clark owned building at 137,000 square feet, was immediately dismissed by both of the Clark Emergency Team Members contacted. They were dead set against the use of the library as an evacuation shelter. The primary reason was the extensive amount of glass on each floor that would make it hazardous for students that could be sheltered there. The other concern voiced by Chief Goulet was the structural integrity of the building itself. Therefore it is not truly a viable alternative and it is only mentioned to show that it was investigated as a shelter. Based upon the feelings of the two Emergency Response Team members contacted there would have to be very few options left for the Goddard Library to be considered as an evacuation location. There are several areas in the library that could be used to house students until transportation for the evacuation of students off campus could be made. There are the stairwells that could house students in them at least temporarily. There are the center stacks, which are protected by brick walls that would shelter students from the worst of a storm, if it were necessary. Also the central stacks would be protected from the majority of debris should a window be broken on that floor. Based on the feelings of the two Emergency Response Team Members contacted this would only be done as a temporary measure and if there were no other options available at the time.

Total Evacuation of Campus to an off-campus location

In the event that the entire campus was compromised and there were no place to safely shelter students, the Emergency Response Team would evacuate the entire Campus population off of Clark's property. When this scenario was discussed it was under the situation was that there were no available places to house students in Clark's owned facilities. The possible shelters had either been compromised or that there is not enough room to house the students in the remaining shelters. There was no specific location listed as to where students would be evacuated to if this step became necessary. The off-campus location would be chosen as the severe storm approached. There was not a specific location chosen as during a severe storm events could change instantly. Therefore it is important in this scenario to maintain flexibility.

An evacuation location should be chosen when the strength and path of the storm is determined so that Clark students are not accidently moved into greater danger. Transporting that many students in a severe storm is a monumental task. There is the possibility that Clark may not be able to procure transportation for a significant length of time during the storm. Several locations should be contacted in advance to see if they can hold Clark's students or if they are already at capacity. A severe dilemma that the Emergency Response Team will face will be whether off-campus students are evacuated with on campus students. Does Clark have an obligation to the off campus students during a severe storm? If Emergency Response Team should leave the off campus students behind what happens if the students are injured or killed? If Clark has an obligation what characterizes that obligation?

Scenario: Clark as the only Functioning Institution

A second scenario is that in a severe storm there is the possibility that Clark could be the only place with still functioning service in the Main South area. If this becomes the case there are several question/scenarios that could arise. The Emergency Response Team Members have openly stated that this scenario has not been thoroughly considered and there is no policy as to what to do in case of these scenarios. If Clark's resources become limited should Clark open its services to the public or are services limited to on campus students? The greatest question we faced was whether or not Clark has the obligation to the outside community during a severe storm.? Should Clark limit its resources to students only? Are off-campus students included or not in this scenario? If Clark denies opening its service to the community how will that affect the future relationship between Clark and the community? There are many questions that can be posed in the event that Clark is the only place with critical services. This scenario has not really been considered by the Emergency Response Team. Further consideration should be given to what may happen during this scenario. The inclusion of this scenario is merely to raise awareness about the possibility of its occurrence and to argue for serious consideration of it. There are many more dilemmas that the Emergency Response Team may face in this situation.

Overall Assessment of Clark's Shelters and Comparison

In the event of a severe storm hitting Clark and requiring the Emergency Response plan to be activated, the first choice of the for where to shelter students is in their dorms. The second choice for housing Students during a severe storm would be that of the Kneller Athletic Center followed by the Dolan Field House. The Emergency

Response Team Members did not specify if they would evacuate all students before a storm or if they would evacuate students only on an as needed basis. The as needed basis would be constituted if a dorm lost power, water, heat, other critical services. The as needed basis could also be used if a section of campus lost power and it could not be restored. There should be consideration given to keeping as many students in their dorms as possible. It may be better to evacuate as few students as possible in the beginning while keeping the rest in their dorms. This would alleviate the stress that would be placed on the Kneller by instead of housing the entire on campus population in and instead only housing the students that cannot stay in their dorms.

Clark has several locations to which students can be evacuated to if necessary. There is a preferred order in which the buildings to shelter in would be chosen. These locations can be used for the duration of the storm and the recovery from it. There are challenges for each of the location, but these challenges if properly managed can be minimized. After the storm it is possible that students can be dispersed to different locations on campus that is demeaned safe for them to use. The most critical decision that needs to be made is where to house the student during the storm, itself. After the storm there are several moral questions that Clark when dealing with the outside community.

A recommendation for the full-scale evacuation off campus is to contact the Worcester colleges, universities, or other institutions to see if they have room to house Clark students in the event total evacuation of the campus becomes necessary. There should be several locations lined up in the event that one or more is compromised by the storm. The Emergency Response Team must decide if they can safely transport the entire campus population and whether or not to include off-campus students in the evacuation. Clark University or future team of the Sustainable University class should consider further investigation on what would be required in order make the library a viable severe storm shelter. A future team should also consider investigating what the structural inherit of the Goddard Library actually is. There is also the possibility that some of the windows can be fitted with storm shutters so that they are protected during a severe storm. These considerations are for a future team to investigate as the purpose section is merely to assess what resources Clark has during a severe storm and to serve a basis for future teams to conduct investigations off of.

In addition, a possible shelter that has just come to attention of this team is that fact that at Clark there is a WWII/Korean War era shelter under Atwood Hall that was at some point converted to a storage facility. With how recently this possible shelter came to the attention of the team, a thorough assessment and investigation of the shelter was not possible. We suggest that either Clark University, or a future team should consider assessing if this shelter is viable evacuation location as well as what would be needed to bring it up to the current safety standards.

In the Emergency Response Plan of Saint Mary's College there is a statement of the responsibilities of Resident Life.(Saint Mary's College Emergency Response Plan) These responsibilities are "assist in the orderly evacuations and or "shelter in place" plans of buildings as needed or ordered, help to assemble evacuees at gathering points defined in the building evacuation portion of this plan, gather names of evacuees while keeping them a safe distance from the building evacuated, and to assist other support teams as needed or requested to provide services to students" (Saint Mary's College Emergency Response Plan) Within Clark's Emergency Response Plan Kevin Forti is

listed as Emergency Response Team Member, there is no indication of what the responsibilities of Residence Life and Housing are (Clark University's Emergency Response Plan). There may be practices in place that are simply not stated in the Emergency Response Plan. It may be of benefit of the University to have an outline of the responsibility of Members of Residence Life and Housing. A future team should consider investigating what are the specific responsibilities of members of Residence Life and Housing are. A consideration should be given to have at least one Resident Advisor per a building trained so that they may be able to assist in an emergency situation. By having these additional resources there would be more trained personnel that Clark could use in the event of an Emergency.

Conclusion

In conclusion, we strongly recommend as extreme storms become more prevalent, that Clark University should strengthen its preparedness for these events. Although, as we have covered throughout this analysis, Clark already has certain systems of preparation in place, further reinforcement in the areas of food security, water security, communication, and shelter should take place in order to minimize hazards to students and staff in the event of a severe storm. It is important to recognize that in this assessment, we only analyzed four major systems that could be affected due to extreme weather. These are not Clark's only vulnerabilities in light of a severe storm, but merely those, which we identified as some of the most crucial to the survival of these events. Although this project has left us with quite a few questions, we hope that this assessment will encourage future action on the part of either Clark University itself, or other student project groups to build upon and generate more effective climate preparedness practices at Clark.

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Bird, Butterfly, and Bee Gardens

Samantha Dokus, Michael Macomber, Erin Wurtemberger

Abstract

Our project focuses on contributing to a larger effort in Massachusetts to increase native plant and animal species. To accomplish this goal we have decided to create gardens that will attract native birds, butterflies and insects with declining populations, such as hummingbirds, monarch butterflies and honeybees.Our accomplishments for this semester include 1) approval for three garden locations on campus, 2) funding to purchase plants in the spring, 3) selecting native plants that will attract native bird, butterfly, and bee species, 4) making arrangements with Physical Plant to install the three gardens in the spring. The outcome will be three garden plots that contribute to this larger effort to increase native species by increasing native plant life and attracting various species of birds, butterflies and insects with declining populations.

Introduction

Clark University is located in the center of Worcester Massachusetts, which is the second largest city in the state (Brinkhoff, 2013). The urban setting does not promote biodiversity; however, this is not the only hurdle to increasing biodiversity on campus. Universities in general do not make the best use of their land, as far as biodiversity is concerned because they are more focused on aesthetics. Most university campuses plant turf grass whenever space allows. Although there are many benefits to turf grass, including the creation of ideal space for people to congregate and being aesthetically pleasing, it is still a monoculture that does not promote diversity of species of any sort.

When planning a landscape, individuals often focus solely on the aesthetics. In doing so, functionality is neglected and the landscape is not used to its full potential. When constructing a landscape, it is imperative to consider both the functionality and aesthetic nature of the entity as a whole (Nassauer, 1993). Keeping this idea in mind, if a landscape is constructed in this particular way, biodiversity and sustainability awareness are increased (Shah, 1998). To address this issue we plan to replace turf grass in three locations on campus to help maximize the use of the university's landscapes. A similar innovation occurred at Warren Wilson College. This institution is turning their turf grass into meadows of wild grasses and flowers. The decision to make this change was based on the amount of hours required to mow the grass each week, unnatural irrigation, and a lack of biodiversity. The scale of this project at Warren Wilson was much larger than the scale of the project here at Clark University, due to the rural setting and space. Warren Wilson College was able to replace three acres of grass with native grass species allowing for an increase of birds, butterflies, bees and insects on their campus (Cross, 2011).

The issue of a lack of biodiversity is important because "greater species diversity ensures natural sustainability for all life forms" (Shah, 1998). Due to the interconnectedness of all life's systems, it is important to increase and maintain biodiversity. We plan to strategically install plants that will attract specific animals with declining populations to the area, therefore increasing biodiversity on campus.

Background

Currently, the landscape is predominantly turf grass. The main purpose of turf grass is to allow for people to congregate outdoors. However, this is not the purpose for most of the turf grass planted around campus. There are many spaces covered in grass that are not meant for congregation, for example, along the side of buildings and walls. If these spaces are covered in grass but are not gathered on then they are not serving their purpose and are not the most effective use of a landscape. However, if we were to install gardens to increase the native species in spaces like these and they did in fact serve this purpose, then this would be an effective use of a landscape.

Last year in the Sustainable University class, there was a project with a similar goal of improving the effectiveness of a landscape (Macedo et. al, 2012). Their project differed from ours because their focus was on creating a garden for human consumption. Their other main objective was to educate people about more creative and sustainable landscaping options. Building on this prior project (which did not result in implementation), our group was able to take a new approach, creating a garden focused on plants for bird and insect consumption. The reason we decided to change the focus of the project from human to animal consumption was due to the conclusions made from the previous year. For example, the fact that harvesting seasons are predominantly in summer, when most students are away from campus, poses timing challenges with a focus on human consumption. With this new focus we were able to identify specific bird, butterfly, and bee species to focus on attracting though plant selection (Macedo et. al, 2012).

The landscape we plan to install will use native plants to help increase biodiversity. Specifically, our goal is to attract common bird species' with declining populations in Massachusetts. Although these species are widespread, collectively their populations are facing decline. "The species predicted to decrease include some of our most familiar birds: Tree Swallow, Black-capped Chickadee, Gray Catbird, Yellow Warbler, and Song Sparrow" (Mass Audubon, 2013). One particular species of bird that will benefit from our edible landscape will be the Blue Jay, which is a common native bird to Massachusetts.

One type of plant we are including in the edible landscape is milkweed, which attracts monarch butterflies. Their caterpillars feed solely on this plant. Due to modern changes in the environment, such as suburbanization, there has been a decrease in milkweed. So, in order to promote monarch population growth, milkweed needs to be available in abundance (Allen, 2013). In addition to milkweed, coneflowers will be planted in the edible landscapes. Coneflowers attract butterflies due to the nectar. Also, birds such as Bluejays, which are a common native bird species, will be attracted to the seeds in coneflowers (Free, 2013). Besides milkweed and coneflowers, blueberry bushes and winterberry bushes will be planted in the gardens as well. The reason that these bushes will be planted is to attract various bird species who will be inclined to eat the berries produced by both bushes. Daylilies are another plant that will be included in the edible landscapes on Clark University's campus. This particular type of plant attracts hummingbirds and will therefore increase the scope of the type of bird that will be attracted to the edible landscapes (Galbreath, 2013). Installing these plants on Clark University's campus will increase the amount of biodiversity on campus by increasing not only plant species, but bird and insect species as well.

Most importantly, edible landscapes add to sustainability awareness. An example of this practice being effective is the University of Worcester in the United Kingdom. By installing a sustainable garden on their campus, the university involved the local community, offering faculty, students, and nearby schools opportunities to volunteer. The university initiated parklands served as a learning focus for the community and provided research opportunities. Overall the parklands and garden increased biodiversity within the university and the community as a whole (Wills, 2013). Similarly to the University of Worcester, Clark University also strives for community engagement and opportunities to increase biodiversity. An edible landscape will contribute to these university goals.

Process

Our team started off the year by reviewing the related project from last year's class. What we found through our initial research was that we wanted to go in a slightly different direction. Once we focused in, we were able to clearly define our desired outcome as a garden that would attract native animal species with declining populations, and were able to take steps to make this a reality.

First, we spoke with Emily Smela, president of the Herban Gardeners club, to get gardening tips and discuss partnering when it is time to install the gardens. Then we reached out to Chip Pybas, head of grounds at Physical Plant, who turned out to be a crucial resource for our project. Chip started us off by scoping out three potential sites for our project, which were chosen due to their difficulty to mow and their central locations. After receiving permission to use any of the three locations it was decided that we would create gardens in all three locations.

Once we established our key contacts, we began to research plants, birds and insects. We determined which native plants would be most effective in supporting the declining animal populations. We also looked at examples of similar projects at different schools, and how to best educate the surrounding community about our project. Once we decided which plants to include, we contacted Chip Pybas, who connected us to Bigelow Nursery, where Physical Plant often purchases plants. With this information, we were able to estimate the cost of the gardens. We developed and submitted a successful application for funding through Clark's Student Sustainability Fund. Through this fund we were awarded $750.00 towards our project, which will cover most of the plants for all three gardens. The rest of the funding will come out of Physical Plant's landscaping budget. The planting of the garden will be executed mid/late May. Physical Plant has agreed to strip the grass from the plots and mulch the areas for us as well as help install the gardens (Chip Pybas, personal communication, Fall 2013). For the remainder of the semester, we met with Chip frequently and further planned our gardens. We have also selected which plants we will include, and designed the gardens.

The steps going into the next semester include preparing for the educational component of our project. We are going to get the word out about the groundbreaking through social media, such as Facebook, and through cafeteria slides. In the spring, we will install our gardens.

Results

The outcome of our project at the end of the Fall 2013 semester includes the design and location of three gardens (Figures 1-7 below) and funding to buy the plants necessary for these gardens. We secured $750 in funding from the Student Sustainability

Fund here at Clark University, which will go towards the purchasing of the majority of the plants that are needed for the gardens. The rest of the funding will come from Physical Plant's landscaping budget, most likely a few hundred more dollars at most. Both plant selection and costs are shown below.

In May 2014 the project will be completed. The final outcome will be the three gardens installed. This will be accomplished by the continued collaboration of the three-team members of this project and Physical Plant. In the spring Physical Plant will strip the garden plots of grass and mulch the areas, they will provide these supplies. They will also pick up the plants from Bigelow Nurseries, where Clark University often purchases their plants and receives a university discount. Physical Plant and the team members will work together to arrange and embed the plants in their preplanned locations. We will look into inviting a local elementary school class to help with this process as an educational experience (Chip Pybas, personal communication, Fall 2013).

Location Pictures and Plot Design Diagrams

Note: These designs are for layout purposes only; they do not represent the amounts that will be planted in the actual gardens in the spring. The actual estimated numbers are represented in the budget plan (next section of results).

Figure 1. Key for plant selection, note some of these objects are what already exist in the spaces; these items include the light posts, the sign, the bench, and the Dogwood tree.

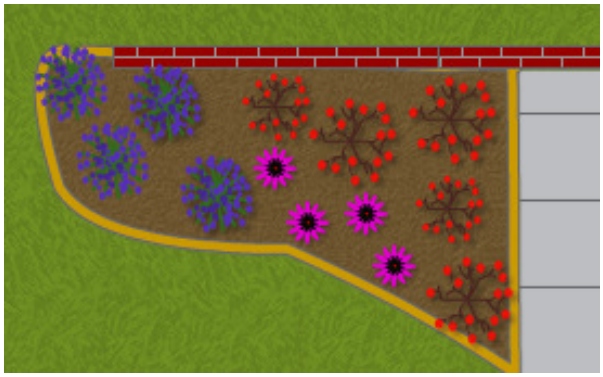

Figure 2 Plot Selection Location One, retaining wall to the left of Wright Hall (Above)

Figure 3 Plot Design Diagram One, retaining wall to the left of Wright Hall (Above)

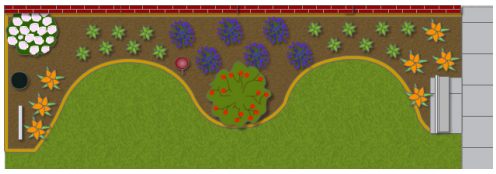

Figure 4 Plot Selection Location Two, Goddard Library, side facing Wight Hall (Above)

Figure 5 Plot Design Diagram Two, Goddard Library, side facing Wight Hall (Above)

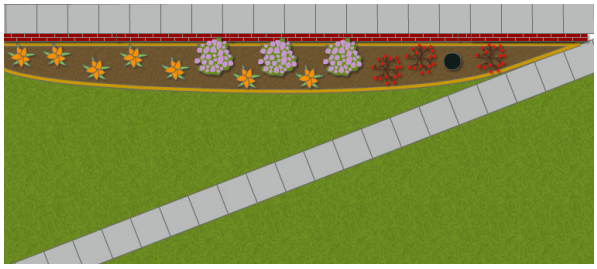

Figure 6 Plot Selection Location Three, retaining wall next to Dodd Hall (Above)

Figure 7 Plot Design Diagram Three, retaining wall next to Dodd Hall (Above)

<u>Budget Table</u>

Product	Individual Price	Number	Total Cost
Winterberry	$14	8 to 12	$112 - $168
Blueberry Bush	$40	6 to 10	$240 - $400

Butterfly Bush	$6	3 to 5	$18 - $30
Oakleaf Hydrangea	$40	1	$40
Daylillies	$12	14 to 18	$168 - $216
Cone Flowers	$12	5 to 8	$60 - $96
Milkweed	$6	8 to 12	$42 - $72
Total			$680 - $1,022

All Prices Estimated from Bigelow Nurseries Wholesale Pricing Spring 2012

Conclusions/Discussion

The outcomes of our project at the end of this semester are three garden plot designs, funding to purchase the plants, and a team committed to installing the gardens in the spring. With these things in place we will be able to move forward with the project in the spring and install the gardens.

The next steps we must take in order install the gardens in the spring are creating PowerPoint slides to be displayed in the dining hall during meals, to spread awareness about the installation of our project. We must also contact local elementary schools to ask if they have a class that would be interested in helping with the installation of our project in May as an educational field trip. We will also have to contact Bigelow Nurseries closer to our planting date to confirm that they have all the plants we have selected in stock and to confirm the prices. Along with this step will be writing a report to the Student Sustainability Fund about how we have used our funding. We will also have to schedule our installation date with Physical Plant so that they can prepare the garden plots for planting in advance. The last step to completing our project is installing the gardens.

These gardens will be important because they will help physical plant reduce work, they will be aesthetically pleasing, and they will increase biodiversity in an urban setting. They will also serve as an example of sustainable gardening.

A big take away that our team had was learning about working within the university system to accomplish a goal, and the hurdles involved with making a sustainable difference. Some of these obstacles include obtaining funding, trying to work within the constraints of the university's desired appearance, and receiving approval for the locations. It is difficult to make a big change at a university, especially within the realm of sustainability, so the desired changes must be specific and realistic. In reality, adding three gardens to Clark University most likely will not increase biodiversity in our region in a substantial and measurable way. However, this effort in collaboration of many other efforts to increase biodiversity could potentially have great effects in this region.

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Human Powered Bicycle Generator

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"Every addition to true knowledge is an addition to human power." Horace Mann

Abstract

People usually use fitness bikes to burn off calories, but what if they could use that energy to make electricity? This is possible using a Human Powered (HP) bicycle generator. By creating our own HP bicycle generator we can increase sustainable energy awareness among Clark University students and make possible suggestions on improving energy efficiency for Clark's Bickman Fitness Center.

Introduction

Climate Change and Fossil Fuels

Over the last 150 years, the amount of greenhouse gases has dramatically increased in the atmosphere, mostly due to human activities. This increase is currently resulting in instability in the climate system. (IPCC, 2013) The largest source of greenhouse gas emissions in the United States is from burning fossil fuels for electricity generation, which produces approximately 33% of greenhouse gas emissions (Environmental Protection Agency, 2011). According to the Environmental Protection Agency our society's reliance on fossil fuels is among the most challenging dependencies to overcome (Environmental Protection Agency, 2011). Therefore changes in how we make, teach, and use energy need to occur.

University Initiatives

Clark University, through its Climate Action Plan, has taken the challenge of reducing its fossil-fuel use and lowering greenhouse gas emissions by signing a commitment to achieving carbon neutrality of the campus energy systems by the year 2030 (Clark University Board of Trustees, 2009). Specific strategies for reaching neutrality are still being determined however, improvements in energy efficiency to reduce energy demand on campus are clearly a critical aspect. In addition, President John Bassett signed the American College and University Presidents Climate Commitment in June 2007. Through this commitment Clark University became one of the top institutions with the goal of decreasing greenhouse gas emissions. (Clark University Board of Trustees, 2009).

Human Power (HP)

One approach to enhancing awareness about energy efficiency and demand is by demonstrating human generation of electricity (Alternative-energy Human Power, 2013). Human Power (HP) refers to electricity created by an individual through energy produced from the human body. Human power can also be considered in terms of the first law of thermodynamics in which energy can be transformed but not created or destroyed (AE News, 2013). This means that the energy humans create is conserved in some form or another. More specifically HP can be defined through the energy cycle- the chemical energy in a person's body is made into mechanical energy through rotations of a device

(bicycle, round-about, etc.) and then converted into electrical energy. Because HP is both abundant and releases no greenhouse gases, many application of HP currently exist (AE News, 2013).

Project Goals

Our team project is at least a two-semester project. This semester involved designing and planning a human powered bicycle generator to be displayed on the Clark campus to enhance energy awareness and thereby setting up the legwork to do so. This involved 1) planning the installation of a HP bicycle generator on campus, and 2) investigating the potential for Clark University to meet its energy demand using HP specifically with regards to the fitness equipment in the Bickman Fitness Center and ultimately making recommendations that would be able to incorporate HP into the center if beneficial. Next semester we hope to be able to assemble our bicycle generator and use it as a demonstration tool for Clark University students.

Background

Types of Human Power

While there are multiple ways of generating electricity, according to an article entitled Electric Power from Ambient Energy Sources, "[e]nergy derived from human activity appears to be the most underutilized ambient energy resource" (De Stesse, 2000). However many current projects involving HP do occur. We have divided these projects into 4 categories with our specific project focusing on HP based on pedal power i.e. a bicycle generator. These 4 categories are: 1) HP Based on Rotary Motion 2) HP Fitness Equipment 3) Other HP Projects 4) Pedal Power

HP Based on Rotary Motion

The idea of HP base on rotary motion is that HP can be operated using the kinetic energy from rotating a revolving piece of equipment and transforming that kinetic energy into electricity. For example Global Inheritance, a nonprofit organization whose mission includes informing "individuals about issues that affect us globally" have developed an energy playground in which playground equipment such as a spinning Merry-Go-Round harnesses the energy used to spin it and then stores this energy as electricity in a battery or to power multiple 12-volt appliances (Global Inheritance, 2013). Another example of HP based on rotary motion is a roundabout developed by a South African nonprofit called Roundabout Outdoor. This installation, called a Play-Pump is used to power water pumps in rural areas of Mozambique and has already had more than 700 installed with plans to install 100 more (Thomas, 2005). Finally in a Netherlands train station a revolving door generates electricity, which is used to power the train station café's LED bulbs. While entering and exiting through a revolving door is not something people have to think about, this revolving door generates approximately 4,600 kWh of energy per year. (Stamats Communications, Inc., 2013).

Therefore whether educating people in the United States about energy generation, providing drinking water to children in rural Africa, or using HP practically to power the lights in a café, HP has potential for global use and can be accessed throughout the world.

HP Fitness Equipment

Many HP fitness companies already exist and use their HP fitness equipment in gyms and fitness centers throughout the country like the Green Microgym in Portland Oregon. According to Owner, Adam Boesel, the Green Microgym expects that it will use approximately half the energy that other gyms use, eventually hoping that the gym will become totally energy sufficient on its own. While HP fitness equipment isn't enough to power the gym completely, the hope is that people who use the exercise equipment will become more aware of their individual energy usage and therefore using energy more sustainably in other aspects of their lives.

One example of a HP fitness equipment company is The Green Revolution, a company based in Ridgefield, Connecticut that retrofits exercise equipment such as stepping machines, elliptical machines, and stationary bikes to generate electricity that feeds into the electrical grid (*Arakaki, Justin et. al., 2010).* In addition, ReRev, founded by Hudson Harr and based in Clearwater, Florida, is another HP fitness equipment company which retrofits ellipticals that are then used in fitness centers throughout the country including other college gyms (ReRev, 2011). Finally Plugout Fitness, based out of Seattle, produces cross-trainers, ellipticals, and stationary bikes which allow people to track how much energy they have generated. This way people are able to see how much energy it takes to produce one Watt of power (a Watt is 1 Joule per second and measures the rate of energy conversion)(Planet Forward, 2011). Other HP fitness equipment companies include SportsArt Fitness, the Human Dynamo, Woodway's Curve treadmill, Pedal-A-Watt, and Siva Cycle.

If, through our project's findings, we conclude that HP is a viable and effective energy option, we may suggest further investigation of these products to be looked at for the Bickman Fitness Center.

Other HP Projects

Other HP projects are also being researched and implemented to convert HP into electricity. This is because HP encourages exercise while producing no greenhouse gases. Furthermore human labor is abundant to produce HP and these solutions are often very adaptable to everyday life.

One example was the creation of the HP sustainable dance floor (SDF) in Rotterdam, Netherlands for Club Watt in 2008. With a mission of bringing energy consciousness to the world, the SDF works by using the kinetic energy from a person's dancing and then converting it into the LED lights used in the club. This means that the floor can react to how fast or how slow the guests are dancing. In this way, people can see how their energy is transformed into electrical energy as well as interact and experience HP directly (Sustainable Dance Club, 2011). Another example is HP generating shoes such as BrightWalk®, Heelys®, and NTT's electricity generating shoe®. This means that something as simple as walking is able to generate electricity ("Power Generating Shoe Insert", 2013). Lastly, a HP soccer ball called Soccket is connected to a rechargeable battery. After 30 minutes of playing the kinetic energy used to kick the soccer ball can be converted into enough electricity to power an LED lamp for 3 hours (Inhabitant, 2013).

As seen by these examples, HP can be used in many innovative and creative ways that allow for fun interactions with energy generation, which may include interactions within everyday life.

Pedal Power

HP, specifically pedal power, can also address the organizational needs of a community in many ways and can be applied as an energy source to communities throughout the world. Whether in remote areas with little access to electricity or in countries where people use electronics on a daily basis, HP can be a useful energy source.

One issue HP addresses is a possible source of electricity generation in developing countries with a lower human development index (HDI). For instance the organization Maya Pedal creates many pedal power machines or Bicimáquinas as water pumps, grinders, blenders, and more. These machines are used internationally to promote small scale, sustainable agriculture as well as educate people about sustainability and conservation. (Maya Pedal, 2010). Another example is an organization based in California called Rock the Bike. While their mission was more about spreading an interest to people for riding bikes than energy awareness, many of their own creations demonstrated the use of HP. For example they modified bicycles to be used for pedal power concerts as well as pedal powered DJ booths and ice cream makers (Rock the Bike, 2013).

Other examples we found were in Tamara Dean's book "The Human-Powered Home: Choosing Muscles Over Motors." For instance, we were interested in seeing that pedal power has roots that trace back to Alfred Traeger's Pedal Powered Wireless Transciever in 1929. This transceiver because it was pedal powered and wireless could be used in rural areas and left the operator's hands free to tap morse code (Dean, 45). Another example is Frederick Breeden's company Just Soap in which Breeden mixes his soaps by using a pedal powered machine. Using this alternative way of manufacturing, Breeden pedals between 20-90 minutes to mix one batch of 440-pound liquid soap (Dean, 122). Another interesting example wasn't even a real pedal powered machine, it was fictional. On the 1960's show Gilligan's Island, in which 7 people attempt to survive on an island, a pedal powered washing machine made by the professor and a pedal powered car were used. This further demonstrates HP's roots (Dean, 188).

HP is therefore also beneficial because the designs can be simple, cheap, and relatively easy to manufacture while increasing the livelihoods of many.

Benefits of Human Power

Using HP such as bicycle generators can produce energy on campus without the additional emission of carbon dioxide and other greenhouse gases. These greenhouse gases contribute to the greenhouse effect in which heat is trapped in the Earth's atmosphere which creates other environmental issues (Alice McKeown, and Gary Garner, 2009). The primary source of this increase in carbon dioxide is a result of fossil fuels (IPCC, 2007). Therefore power generated by HP could lead to reduced grid electricity consumption, which would decrease the amount of fossil fuels (coal, oil, natural gas, etc.) used by utilities to generate power. This is important because economic indicators indicate that the demand for energy, particularly electricity will continue to grow (Beér, 2004).

HP can also encourage people to exercise. According to a survey conducted by Katy Cleminson, 65% of Clark University students said that they would be more likely to use HP equipment more frequently if they knew that it would help decrease the gym's energy consumption (Cleminson, 2011).

Human Power and the Community

This project, if communicated properly to the surrounding community, could assist Worcester in reaching its goal of becoming "a leader in sustainability", a goal communicated through their own climate action plan (Williams, 2006). Additionally, this project could serve as an example for other fitness centers and colleges, both in and out of Worcester. For instance there are already other fitness centers that use HP to power their gyms. One example in Hadley, Massachusetts is Energia Studios which uses Green Revolution HP fitness equipment to send electricity directly to the electrical grid (Questline, 2013). Thus, gyms like the YMCA of Central Massachusetts may also look to these gyms that use HP as a model.

We will use our project as a way of broadening and promoting HP using Clark as an example. While energy use isn't something that other students think about on a daily basis, we believe that our project will make the issues of energy conservation and generation more visible to students at Clark by demonstrating how much energy it takes to produce one Watt of power. Students will therefore visualize the efforts it takes to produce this energy and learn that using less power is just as important as creating more. In addition "people follow the lead of other people they know and trust" (Gawande, 2013). Therefore, by having students advocate these issues to other students, the ideas will be much more effective.

Our HP bicycle generator could also supplement Clark's Climate Action Plan especially the second phase which lists "a focus on energy systems and energy efficiency as the largest component" to reach a goal of climate neutrality by 2030 (Clark University Board of Trustees, 2009). The Climate Action Plan also calls to "fostering a community that is aware of the impact of behavior on campus energy consumption" (Clark University Board of Trustees, 2009) as well as encouraging student involvement in the implementation of the climate action plan.

Process

Research

We first began by researching other universities that have completed similar projects in the past. For instance, a group at the University of California Santa Cruz has built several PPPM's. Their sustainability committee (UCSC Carbon Fund) sponsored a bicycle generator project in 2012-2013. Students and faculty of University of California Santa Cruz paired up with Natural Bridges High School to design and build two bike generators. According to their website, "[s]tudents at NBHS have been able to power appliances such as blenders and speakers. They now feel engaged and more connected to their personal power consumption." They used the bicycles for blenders and speakers, which is shown on the photo on their website and can be used at small concerts or their milk shake festival (UCSC Office of Sustainability, 2012).

Another institution, Southern Arizona University, also took part in the bicycle generator project. Their project became even more effective because they spread PPPM usage in variety schools of the state of Arizona. "The students were presented with the design challenge, as well as tools and materials, and worked with our staff to design and build the bikes. These bikes were used at several school events and in the classroom the following year as a teaching tool." From 2010, with the great help of NAU student Matt Petney, as the constructor and with growing usage and funds, various generator bicycles were created (ISES, NAU, 2012).

Installation and Demonstration

Next, we did a lot of research deciding what specific type of HP bicycle generator we would like to install at Clark. We chose David Butcher's Pedal Powered Prime Mover (PPPM) design because of its high efficiency to generate power. As opposed to a regular bicycle generator, this design uses the direct connection of the DC generator to a 36" diameter flywheel. This keeps the power generated more constant and multiple generators can be connected to provide enough power to operate electrical devices though an inverter (David Butcher, 2013). Additionally, according to Tamara Dean, this generator is 25% more efficient because it uses a friction drive rather than a chain drive (Dean, 2008).

In the past Clark has had bicycle-powered movie nights, smoothies, and concerts but has had to rent the bicycle generator instead of using its own. Therefore it would be more cost-effective and efficient if Clark had its own portable bicycle generator to use for these events and various demonstrations. These demonstrations show how HP can be harvested as energy and then used later to power appliances such as blenders, projectors, LCD TVs, etc. Most importantly, with increased awareness we hope that these demonstrations will help change unsustainable behaviors with regards to electricity usage at on-campus at Clark. These behavioral changes would hypothetically make students waste less electricity and therefore emit less carbon into the atmosphere.

Funding and Partners

Another piece of planning for a HP demonstration on campus involved searching for funding. We developed and submitted a 20-page application including a section for budget and fundraising, a Gaant chart timeline, tracking and reporting, and outreach and education. In terms of the budget we requested approximately $1300.00 from Clark's Student Sustainability Fund (SSF) for building 3 HP bicycle generators for powering appliances on Clark's University campus and using as a demonstration for energy awareness.

This application was a great way to get in touch with other clubs on campus as the Student Sustainability Fund committee required that we provide a list of partnering faculty, student groups, and organizations that would be involved in the project. Therefore we sought out the Clark Sustainability Collaborative (CSC) to partner with us. After meeting with a member from the CSC, Xavier Pierre-Jerome, they agreed to partner with us meaning that they would take temporary ownership of the bicycle generator and provide us with a small amount of funding as well.

We also made contact with Clark's Bike Share, which provided us with donations of 3 bicycles to use as parts for our installation. We also contacted Professor Charles Agosta, who is also chair of the physics department. He was willing to help us construct the bicycle generator and provide a location of construction at the basement of Sackler Science Center. Additionally he stated that he would use our generator as a demonstration in one of his renewable energy courses. In addition, we contacted one of Agosta's students, Andrey Shilo, who has built a generator before and was willing to help us with our project as well. Furthermore Jenny Isler, Clark's Sustainability Coordinator offered Sustainable Clark to store the generator over breaks when it was not in use. Physical Plant also offered us a location of either the Sackler Science Center or Lasry as a permanent location for our generator. Finally our professor, Jennie Stephens, offered to be the faculty administrator for our project and oversee its progress.

Bickman Fitness Center Research

The second part of our project involving estimating the amount of electricity that could be generated by human power at the campus fitness center. Through communication with Patricia Cronin (the head of Clark's fitness center), we obtained data on the number of people using fitness equipment in the Bickman Fitness Center, specifically the ellipticals, treadmills, and bicycles. We wanted to use the data to get an idea of whether it would be beneficial to harness human power from the ellipticals and the bicycles which do not use any electricity (or only small amounts) and power the treadmills which do use electricity.

The data that was collected from Clark's Bickman Fitness Center is from a three month period at 15 minute intervals every hour the gym was open by Bickman Fitness Center student staffing. The data consisted of the number of people using the treadmill, elliptical, and bike at each interval. These numbers were averaged into hour long increments to obtain the average number of users each hour and each day and then averaged with the data from the corresponding day.

We also surveyed the fitness equipment present in Bickman as part of our analysis. The majority of the fitness equipment in the Bickman Fitness Center are from Precor. This includes RBK815 and 885 recumbent exercise bicycles, EFX 833, 835 and 883 elliptical trainers, and TRM885 treadmills. These are commercial systems and are almost all powered by external electricity (Precor). The 880 series Precor devices all require external power for the model P80 display console and control system. Some of the ellipticals and bicycles were not plugged in as they are self-powered. In these, the work done by the person exercising is turned into heat using a magnetic system similar to a generator. Precor provides data on how much energy the recumbent bicycles turn into heat – at level 1 and 20 RPM 20 W are produced while the maximum power occurs at level 250 and 150 RPM which produces 750 W. While the latter is not sustainable for long periods of time it indicated a great potential for energy generation if systems like the PPPM were used instead.

Treadmills are equipped with a 4 horsepower electric motor that requires large amount of external power to turn the belt. A 2009 study of treadmills from five different manufacturers showed that average power consumption ranged from 379 to 787 W (Life Fitness, 2009). Because standard treadmills require such a large amount of energy we compared the usage of treadmills to combinations of bikes and elliptical.

Analysis of the data from September 11 to November 17 (with a few weeks of missing data) represented a large enough set of data to be representative of user choices. Figure 1 shows the data from 55 different days. The two series in the bar graph are the person-hours each day on the treadmills (red) and the combination of bicycles and ellipticals (blue). The first thing to note is that in general the latter category is greater than the former. The average for the 55 days for the treadmills is 143 person-hours per day. The average of the sum of the bikes and ellipticals was 186 person-hours per day. The average ratio was 1.30. This was representative of most days, as can be seen in Figure 2. The ratio is plotted for each day, and ranges from 0.81 to 2.6.

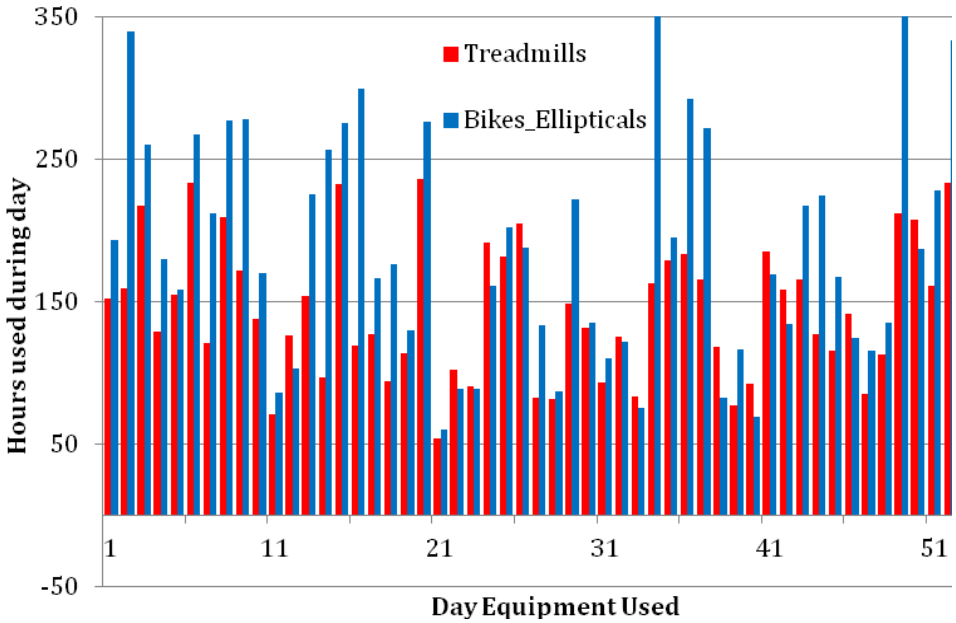

Figure 1 Fitness center daily use of exercise machines. The data is divided into two series, as the treadmills consume large amounts of electrical power, while the bikes and elliptical could potentially provide power.

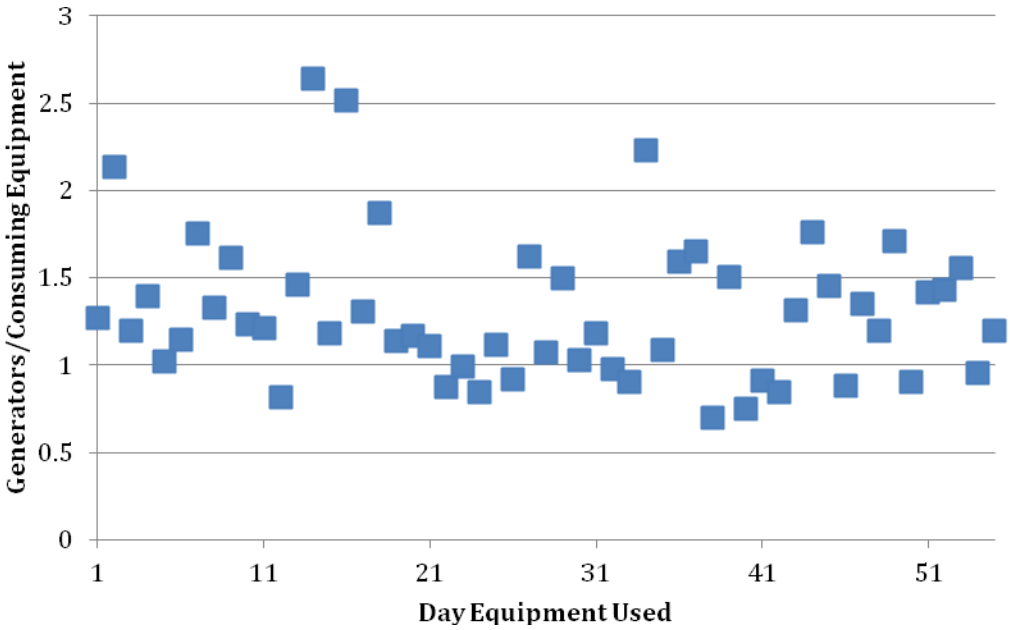

Figure 2 Ratio of Treadmill hours to bike and elliptical hours for each day studied

Results/Discussion

Our research showed that if the fitness equipment at Bickman was designed to generate human powered electricity, the total contribution to the campus' energy needs would be minimal. A typical bike generator powered by a fit person can produce 100 watts continuously. If a person pedals for an hour a day, 30 days a month, that's 3000 watt-hours, or 3 kWh. That's less than 1% of what a typical family uses in a month (920 kWh). So only 0.3 % of energy per month would be generated. The average cost of U.S. electricity is 12¢/kWh, thus one month of pedaling saved you $0.36 for each user of the bicycles. If the system cost $400, it would take a LONG time to pay for itself, even if the bicycle was used for the entire time that Bickman was open.

This project investigated the potential for Clark University's newly renovated Bickman Fitness Center to meet its energy demand using HP generated from fitness equipment in the Bickman Fitness Center. Though the results have shown what we expected - the potential power generated from the fitness equipment would not be sufficient to meet the entire energy load of the Bickman Fitness Center, this demonstrates the significance to consumers on how challenging it is to generate power, which supports the Clark's Climate Action goal of carbon neutrality.

Because the Bickman Fitness Center was recently renovated, changes related to HP in that facility are unlikely. However, changes in the future may still want to be explored. For instance our data suggests that the use of current treadmills, which require several hundred watts of external electrical power, can be partially offset by power that could be provided by pedal power or elliptical trainers. Since the ratio shown in Figure 2 is greater than one, if all bikes and elliptical trainers produced 100 W of electrical power, a small energy storage system, like batteries, could be used to power to power treadmills. One thing to notice however is that the 2009 study on treadmills suggested that they

require ~500 W when in use. As a result five bikes or ellipticals would be needed to run one treadmill. There are potential solutions. Our study suggests that if we educated students on the amount of energy required by treadmills, they may switch more energy efficient exercise machine, such as to bikes or ellipticals, since there already are a greater number of users for the latter (Figure 1). The selection of exercise machines, such as the Woodway Curve, a new curved treadmill that require no external power (Woodway, 2012) or ellipticals and bikes that are self-powered to can produce energy, can reduce the energy needs of fitness centers as well.

Unfortuantly our proposal to the Student Sustainability Fund committee was not funded due to the lack of a specific location for the generator. Even after this obstacle occurred, we continued to explore location options. We have now received agreement from National Grid's Sustainability Hub (after discussions with Rita Moran, the National Grid employee responsible for managing the Hub) that the Sustainability Hub could be the location for the generator. This means that we will be able to reapply for the Student Sustainability Fund in the spring. Furthermore, other funding options should be evaluated.

Conclusion

Our research has shown that electricity is indeed one of the most challenging energy dependencies to reduce. Our project also concludes that although human powered electricity generation may not seem practical as a dominant electricity generation source, its potential should not be ignored. Demonstrating how much human power it requires to generate even a small amount of electricity is a valuable approach to raising energy awareness. With support from physics Professor Agosta and Clark's physics department student volunteers, the Human Powered Bicycle construction will take place at the basement of Sackler Science Center. After designing and building the model, it will be installed at the Worcester's National Grid's Sustainability Hub, at 912 Main Street. This location fits our goal of educating energy efficiency for not only within Clark's campus but outside of it as well. There is a challenge regarding the budget due to the rejection from Clark Sustainability Fund, but with support from the physics department and donations from Bike Share, this project can be successfully completed. Despite multiple challenges this semester, our project has set in motion a plan for demonstrating human powered electricity generation on Clark's campus. We are optimistic that the installation will be successful at a later point when further funding is recieved.

Key Contacts and Collaborators

Rita Moran (The Head of the National Grid's Sustainability Hub)
Patricia Cronin (Assistant Athletic Director of the Kneller Athletic Center at Clark University)
Charles Agosta (Professor and Chair of Physics at Clark University)
Jenny Isler (Campus Sustainability Coordinator at Clark University)
Jennie Stephens (Associate Professor of Environmental Science and Policy)
Andrey Shilo (Student at Clark University)
Xavier Pierre-Jerome (Student at Clark University and Member of the Clark Sustainability Collaboration)

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ASSESSING URBAN RESILIENCE IN WORCESTER, MA

Sanjiv Fernando and Cameron Catarius

ABSTRACT

Climate change is having unprecedented impacts on people and the environment. While many rural and coastal areas around the world feel the effects of climate change, cities are becoming increasingly vulnerable to climate stressors as well. Many cities are unprepared for the consequences of climate change, and it is for this reason that the Environmental Protection Agency (EPA) is developing a tool to assess urban resilience to climate stressors. Worcester, Massachusetts was selected as one of the pilot cities to assess urban resilience, and the study was conducted over four months, from September to December 2013. The CADMUS Group, an environmental consulting firm, was hired to aid the EPA in the creation of the urban resilience tool, and Clark University faculty and students were involved in this process as well. Interviews were conducted in eight key sectors: Economy, Energy, Land Use, Natural Environment, People, Telecommunications, Transportation, and Water. For each sector, a set of questions (with corresponding resilience scores) and indicators were used in interviews with experts to assess where the city of Worcester lies in terms of urban resilience. It was discovered that Telecommunications and Natural Environment were the sectors that displayed the highest resilience to climate stressors, while the Energy, Land Use/Land Cover, and Transportation sectors indicated the lowest resilience. Overall, Worcester as a city appears to have moderate climate resilience, but there is no standard to compare it to as yet, given that this is a pilot project. This is a preliminary contribution to assessing urban resilience to climate change

Introduction

Resilience to climate is a growing concern in the world (Adger 2000,2003; Holling 1986, & Tanner 2009) as mitigation has done little to stem climate change (IPCC 2011). The US Environmental Protection Agency (EPA) has funded a project to develop a tool to assess urban resilience to climate change. Questions guiding this work includes: what systems are needed to sustain human life in the urban area? How would climate stressors affect these systems? The EPA plans to develop and apply indicators associated with a critical threshold to enable assessment of urban vulnerability to climate change (Cadmus 2013).

To develop this urban resilience tool, EPA and Cadmus decided to focus on two pilots cities: Washington DC and Worcester, MA. These two cities, which are quite different, would serve as examples within which to explore the development of a tool to assess urban resilience to climate change. The CADMUS Group established two methods for data gathering in the Worcester case study based on interviews with experts: the first involved a set of sector-specific questions (Holden 2005) and the second involved a set of sector-specific indicators (Keeble 2003; Tanner 2009). In a study conducted in Asian cities Tanner (2009) created a framework, to look at climate resilience of cities. In the case of the Tanner study a five point framework describes decentralization and autonomy, accountability and transparency, responsiveness and flexibility, participation and inclusion and experience and support. The methods for selecting the stressors were established in a 14 step flow chart that involves identifying the data and scoring whether

or not the stressors are relative on a threshold (Cadmus 2013/ Figure 1). Climate stressors can occur in two forms, gradual changes and extreme events. Gradual changes refer to wind speed, temperature, precipitation and sea level rise; while extreme events encompass heat waves, drought, floods, hurricanes, ice storms, and flooding (Tanner 2009)

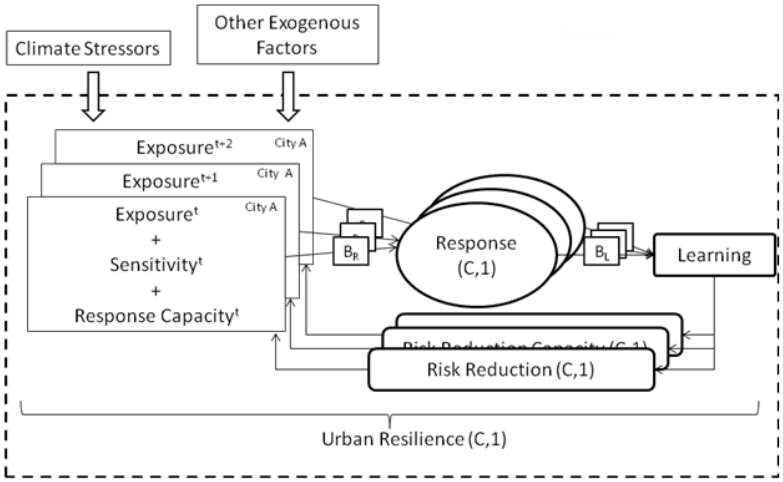

Figure 1: The 14-Step Flowchart developed by The Cadmus Group to assess climate resilience in cities.

Indicators are often used to create and assess a critical threshold level. The idea of using indicators is not a new one, and many organizations use a set of indicators and thresholds to assess how they are doing (Keeble 2003).

One approach to considering how particular indicators are selected is demonstrated in Figure 2 (Keeble 2003*)*. The flowchart below (Figure 2) describes basic criteria for an indicator. Indicators must: 1. be relevant, 2. have relevant commitments to the source, 3. have a benchmark to work off of, and 4. explain what is expected (Keeble 2003*)*. So for an indicator to be chosen it must fill the four requirements and then it can be considered to be shortlisted, and after more careful sorting indicators can be selected. This process can be quite a long one; however this ensures that the indicators directly correlate to the project in question. Indicators provide a metric to assess a larger complex system.

Background

The EPA and Cadmus have focused this project around eight sectors: economy, energy, land use & land cover, natural environment, people (public health and welfare), telecommunications, transportation and water. These eight sectors are to be explored through a set of interviews with representatives from each sector in which both a set of questions and indicators will be assessed.

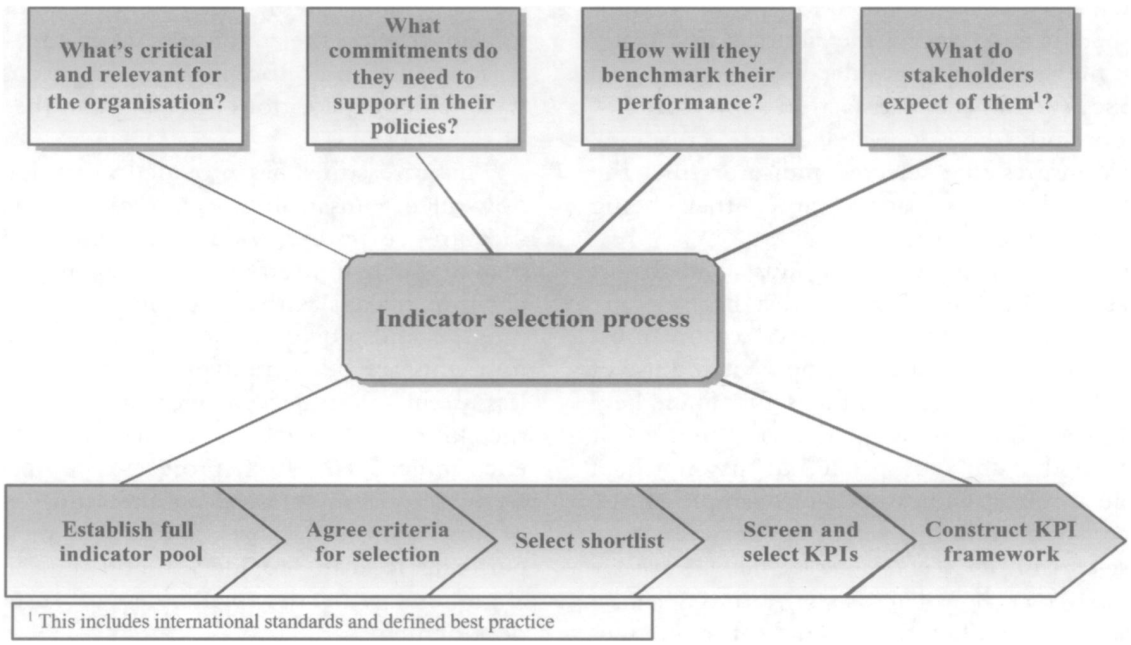

Figure 2: Indicator Selection Process (Keeble 2009)

The economy in Worcester has changed from textiles that stem from the Blackstone River to one that is entwined with higher education and biotechnologies (Worcester 2013). How does a city show that their economy is resilient? For one the people want changes towards sustainability from the companies where they shop (Keeble 2003). If the people want changes to happen, and more and more popular demand for resilient commodities is created it is possible for a market opening up that reflects these ideals (Hark 2003*)*. The rise for sustainable economic policy is not just from the people there is also cries for reform from the companies themselves, as they realize that their practices are not sustainable (Roberts 2004). An idea exist that advocates for a self-sustaining, city-wide economy that can also interact with the outside economies (Adger 2003*,* Bailey 2007*)*.

The sector of energy deals with how the city uses energy, and where electricity and fuels come from. There are ways of reducing energy in ways that could in some cases reduce energy use down by 50% (*Pimentel 2008*). To look at a city and wonder where its energy comes from is a large part of what people want (Beatley 2008). However what is energy resilience? This is the question that Grove and Burgelman ask in their paper (Grove and Burgelman 2008). They argue that to get the US off foreign oil it would be necessary to decrease the US's dependence on oil (Grove and Bergelman, 2008*)*. They use the case of the electric car to demonstrate the US could decrease how much oil it imports, which would increase energy resilience (Grove 2008*)*. The point that the paper is making is that outside sources of energy reduce energy resilience (Grove 2008)

Land use & land cover is another key sector. This sector deals with how the city is zoned and where people live and work (Clive 2006*)*. How a city is planned can show how adaptable the city is to changes (reference). In 1994 a paper was published that

looked at city that was planned to be built on nearby wetlands (Owens 1994). To make a resilient plan, the environment should be left alone as much as possible, to allow for a stable ecosystem (Owens 1994). There is a prescribed process that would allow for the most resilient of neighborhoods (Clive 2006). One of these steps is to decrease the distances need to travel from living, working and commercial districts, the second and third steps ask about the amount of private and public green space compared to the amount of people living in the area (Clive 2006).

The natural environment is a sector that is a look at the biodiversity of the urban area both stagnant flora and the mobile populations; fauna. The ecology of urban places is in a declining state where humans rest at the highest trophic state and all other fauna rest below; meaning humans consume the most amount of energy in the form of food (Evans 2011). This being said the number of species that sit lower than the humans have a less stable ecology because the humans import food and their establishments decrease the amount of natural food sources especially at the lowest Trophic level, i.e. plants (Elmquist 2004). The stress that people have on the ecosystem is enormous, a focus on the pest killing is a large part of what happens in a city and at the same time when people do this there is a loss in trophic scale in the ecosystem i.e. energy is lost. The amount of energy lost to the primary predator (humans) is sufficient enough to keep the secondary predator population low to the point where it is difficult to find food and therefore reproduce (Elmquist 2004*)*. So to increase the level of prey diversity that humans would not find the need to cull would allow for natural levels of population growth in the urban area, and a healthier ecosystem will be able to bounce back faster.

Sustainability for people i.e. health can be difficult to be looked at and in modern times it has fallen to the bottom of the pecking order the health of the urbanite (McMichael 2006). The advancement of medicine has been a swift one once the west had the idea that people deserve to live (McMichael 2006). However, in the modern world the desire for people to better the system has gone down. The people see no issue with the way the world works and for that there has been no change to make the medical world more self-sufficient and in some cases less advanced to allow for people to have some chance when the advanced methods are unavailable due to the changes in the natural environment (McMichael 2006*)*.

Next, there is the Telecommunications sector. How does this relate to people well if the people cannot communicate then how are they going to acquire emergency medical attention. Therefore telecommunications is a look at communication during an extreme event, i.e. police and fire communication as well as to allow for the people to get updates on how they are doing during an event (Holden 2005). The police and fire need to be able to talk around tall buildings as well as during events where communication may not be possible so in a way of resilience if the police can still talk back and forth with all others cannot then the city is more resilient to one where communication is easily lost (Holden 2005).

Transportation, for a city how people get around is extremely important, what happens when people cannot move from place to place? Cities depend on the use of private and public transportation. The more public transportation the better, because most of the time they are made for the mass movement of people i.e. trains, or buses (Beatley 2008). The private sector of transportation does not allow for the mass movements of people, like taxis and personal cars (Beatley 2008). One of the main producers of CO2 in

the US is cars the more cars on the road the higher the level of CO2 is produced (USDS 2007). Transportation can become easier if the commute of people was shorter and the amount of public transport was higher (Clive 2006, Beatley 2008).

Water carries a duality in a city it is there sewage and there for drinking (Petts 2007). of the first, sewage; a city that treats and cleans its waste water is higher up on the pecking order in resilience due to the fact that less water is lost to sit in vats allowing for the reuse of waste is extremely valuable (Elmqvist 2004). The second look at water is the need of drinking water (Petts 2007) the closer natural sources of water are to the Urban environment the better for the people because even if there is issues with pumping water far distances there is still the fact that there is water nearby (Petts 2007, Owens 1994) So the health of local water sources must also be of great importance to the urbanite (Petts 2007).

Methodology

This project was initiated and funded by the United States Environmental Protection Agency (EPA), who hired CADMUS consulting group to carry out the assessment of Worcester's Urban Resilience. CADMUS then reached out to faculty in the Environmental Science department at Clark University, specifically Dr. Jennie Stephens, Dr. Tim Downs, and Dr. Steve McCauley. Both Dr. Stephens and Dr. Downs provided students with the opportunity to work with them on collecting data for this project. As students of Dr. Stephens' course "The Sustainable University", we were able to work on this study as the independent research project upon which the course was based. Our main duties were to communicate with Dr. Stephens and conduct interviews with Worcester City officials in order to collect data to help assess urban resilience in Worcester. The figure below illustrates the main people and organized in the project.

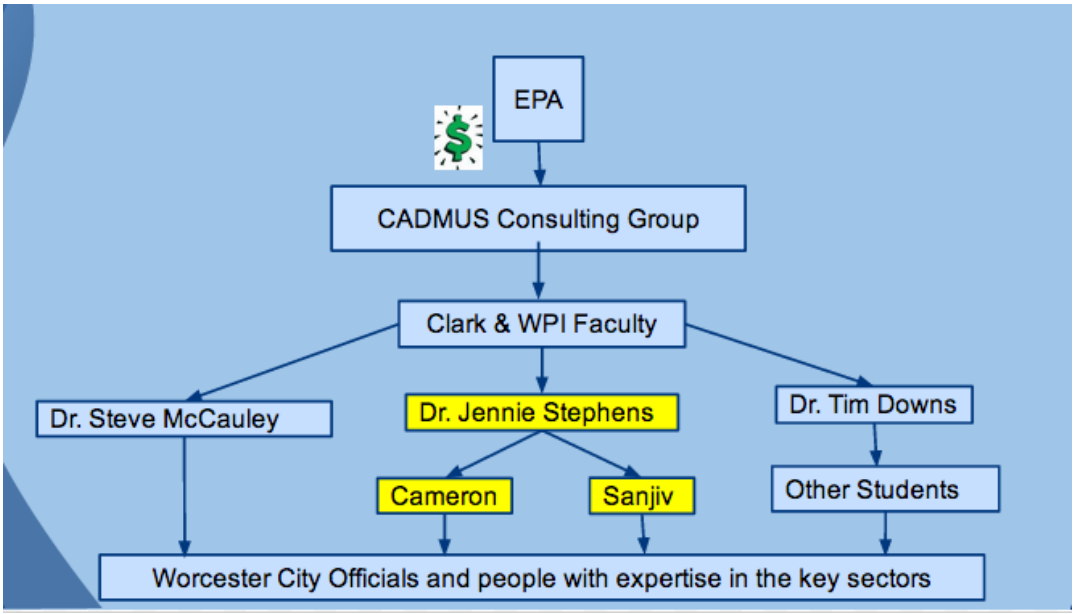

Figure 3: Flowchart explaining the project collaborators and the mechanisms of the study

In order to collect data to assess urban resilience, a 5-step process was implemented for each sector. The five steps are:

1. Find an expert
2. Schedule an interview with the expert
3. Conduct the interview - ask questions prepared by CADMUS
4. Compile and analyze data from the interview
5. Create a report to present and publicize the findings of the study.

Along with Dr. Jennie Stephens, we were involved in all five steps for the Energy, Land Use/Land Cover, Natural Environment, and Telecommunications. For the Economy, People, Transportation, and Water sectors, we were only responsible for steps 4 and 5 as Dr. Tim Downs and his students accomplished steps 1 to 3.

Interviews

All the questionnaires were in a format reflective of multiple choice, where options for responses were given along with corresponding resilience scores. There are two types of questions on the questionnaire used in the interviews. One type of questions requires a Yes or No answer, while the other requires a more relative answer. For the latter, a range of options is provided with each option linked to a resilience score. During each interview, we would first ask if each question was relevant (to the specific sector and to Worcester), then ask how important the question was considered to be on a scale of 1-4). Once we had done this for all the questions, we would then go back to all the questions marked as relevant, and ask the expert to provide and answer and resilience scores to the question.

A comprehensive description of the interviews for each sector is provided in the following pages, complete with details of the names of the experts who were interviewed, as well as selected questions that were asked during the interviews.

1. ECONOMY

A representative from the Worcester Regional Chamber of Commerce was chosen as the expert for this sector, and was interviewed in order to assess the resilience of Worcester's Economy to climate stressors. The questions in this sector were very diverse, with topics ranging from the financial capacity and credit risk to the vulnerability of critical infrastructure. Overall, a large number of questions focused on a variety of planning issues such as comprehensive adaptation planning, climate change adaptation planning, and the flexibility of planning strategies. Two example questions (#5 and #11) are provided below along with the options for the answers and their corresponding resilience scores.

#5: Has the urban area's resilience to major changes in energy policy/prices been assessed?

Answer	Resilience Score
Yes	1 (lowest resilience)
No	3 (highest resilience)

#11: How flexible are planning processes for short-term and long-term responses? For example is there flexibility in planning priorities if necessary?

Answer	Resilience Score
Planning processes are fairly inflexible	1 (lowest resilience)
Planning processes are somewhat flexible	2
Planning processes are moderately flexible	3
Planning processes are very inflexible	4 (highest resilience)

2. ENERGY

John Odell, Energy Manager of the City of Worcester was selected as the expert for this sector. He was interviewed on September 11th 2001 to provide insight and assist in determining the resistance of Worcester's energy sector to climate stressors. Questions touched on numerous issues such as energy demand, the diversity of the energy portfolio, and power outages. The questions listed below represent two examples of the questions asked in the interview.

#22: To what extent have efforts been made to reduce energy demand?

Answer	Resilience Score
Few efforts have been made to reduce energy demand	1 (lowest resilience)
Fair efforts have been made to reduce energy demand	2
Moderate efforts have been made to reduce energy demand	3
Significant efforts have been made to reduce energy demand	4 (highest resilience)

#24: Are there smart grid opportunities to manage demand?

Answer	Resilience Score
Yes	1 (lowest resilience)
No	3 (highest resilience)

3. LAND USE/LAND COVER

The Acting City Planner for the City of Worcester, Luba Zhaurova was chosen as the expert for this sector. She was interviewed on November 7th 2013 in order to help determine Worcester's resilience to climate stressors in the Land Use/Land Cover sector. Questions in this sector focused on a variety of issues including reducing urban heat, tree canopy cover & open green spaces, and zoning policies & practices. Two questions asked in the interview are listed below as examples, complete with the answers with corresponding resilience scores.

#31: What percentage of open/green space is required for new development (to encourage increases in such space)?

Answer	Resilience Score
No open/green space is required for new development	1 (lowest resilience)
A small % of open/green space is required for new development	2
A moderate % of open/green space is required for new development	3
A high % of open/green space is required for new development	4 (highest resilience)

#35: Are there codes to prevent development in flood prone areas?

Answer	Resilience Score
Yes	1 (lowest resilience)
No	3 (highest resilience)

4. NATURAL ENVIRONMENT

Rob Antonelli Jr., the Assistant Commissioner of Parks & Recreation for the City of Worcester was chosen as the expert in this sector. He was interviewed on October 23rd 2013 and his responses were used to assess the resilience of Worcester's natural environment to climate stressors. Questions asked in this interview encompassed various topics such as open and green spaces, native plant/animal species, air & water quality, and ventilation. Listed below as examples are two questions that were asked in the interview, along with the answers and their related resilience scores:

#47: Does the urban area coordinate with other nearby entities on water quality?

Answer	Resilience Score
Yes	1 (lowest resilience)
No	3 (highest resilience)

#52: Has an analysis of areas with good ventilation (e.g., aligned with prevailing breezes, good tree canopy cover) been completed?

Answer	Resilience Score
An analysis of areas with good ventilation has not been planned/completed	1 (lowest resilience)
An analysis of areas with good ventilation is planned	2
An analysis of areas with good ventilation is in progress	3
An analysis of areas with good ventilation has been completed	4 (highest resilience)

5. PEOPLE

It was decided that a representative from Worcester's Department of Public Health would be the expert for this category as it focused mainly on public health and welfare. Questions in this sector were extremely diverse, ranging from evacuation and shelter options to response capacities of public health agencies to education programs dealing with adaptation to climate change. Two sample questions taken from the interview questionnaire are provided below.

#61: Does the city have the capacity to provide public transportation for emergency evacuations?

Answer	Resilience Score
Insufficient capacity	1 (lowest resilience)
Fair capacity	2
Moderate capacity	3
Extensive capacity	4 (highest resilience)

#143: Are early warning systems for meteorological extreme events available?

Answer	Resilience Score
Yes	1 (lowest resilience)

No	3 (highest resilience)

6. TELECOMMUNICATIONS

Initially, it was difficult to decide between choosing a representative from the private sector or a Worcester City official to answer questions in the telecommunications sector. After careful thought, David Clemons, the Director of Emergency Communications and Management for the City of Worcester was chosen as the expert in this sector. In his interview, he answered questions regarding issues including but not limited to telecommunications infrastructure, emergency communication methods, and the location of data centers. Some examples of the interview questions are given below.

#76: How would a temporary loss of telecommunications infrastructure affect the local and regional economies?

Answer	Resilience Score
Major effect	1 (lowest resilience)
Moderate effect	2
Small effect	3
Little to no effect	4 (highest resilience)

#90: Does telecommunications infrastructure have the capacity for increased public demand in an emergency?

Answer	Resilience Score
Yes	1 (lowest resilience)
No	3 (highest resilience)

7. TRANSPORTATION

A representative from the Central Massachusetts Regional Planning Commission (CMRPC) was selected as the expert for the Transportation sector. He was interviewed on November 22nd 2013, and his responses to CADMUS's questionnaire were used to determine the resilience of Worcester's transportation division to climate stressors. Questions in this sector were very diverse, inquiring about subjects ranging from the replacement of aging infrastructure to the flexibility of the transportation system, community familiarity with evacuation procedures and much more. Selected questions from the interview are provided below, accompanied by the answers and their linked resilience scores.

#107: What flexibility has been built into the transportation system (different modes)?

Answer	Resilience Score
1-2 modes available	1 (lowest resilience)
3-4 modes available	2
5-6 modes available	3
7 or more modes available	4 (highest resilience)

#119: Have new or innovative materials been tested that may be more capable of withstanding the anticipated impacts of climate change (e.g., higher temperatures)?

Answer	Resilience Score

Yes	1 (lowest resilience)
No	3 (highest resilience)

8. WATER

This sector was special as two sets of interviews were conducted for this sector. One interviewee was an official in the Department of Public Works for the City of Worcester, and the second interviewee was a representative from UBPAD. Questions varied greatly in this sector, focusing on topics included but not limited to water supply, waste water treatment, drinking water availability & testing, and water demand. Sample questions from the original interview questionnaire are given below.

#121: Does the water supply draw from a diversity of sources?

Answer	Resilience Score
Yes	1 (lowest resilience)
No	3 (highest resilience)

#166: Is backup power for wastewater collection and treatment provided?

Answer	Resilience Score
No backup power is provided	1 (lowest resilience)
Minimal backup power is provided	2
Some backup power is provided	3
Full backup power is provided	4 (highest resilience)

Results

Figure 4 presents a summary of the average resilience scores (ARS) of each sector and compares the eight sectors. The overall average resilience score of all the sectors combined was calculated to be 2.58. This data suggests that in Worcester, telecommunications is the sector most resilient to climate stressors (with an ARS of 3.06), and energy is the sector that is least resilient (with an ARS of 1.88). The Natural Environment sector also demonstrates high resilience, whilst its transportation and land use departments are indicative of low resilience. The graph could be rearranged in a way that would show a relatively normal distribution of the data. Half of the sectors studied are above the overall average of 2.58, while the other half fall below it. The four sectors that perform above average in terms of resilience are People, Economy, Natural Environment, and Telecommunications. This leaves Energy, Land Use/Land Cover, Transportation, and Water to make up the lower, less resilient half of all the sectors studied.

A detailed breakdown of the results in each of the eight sectors is presented in the following pages, with data displayed and analyzed in both text and graphical formats.

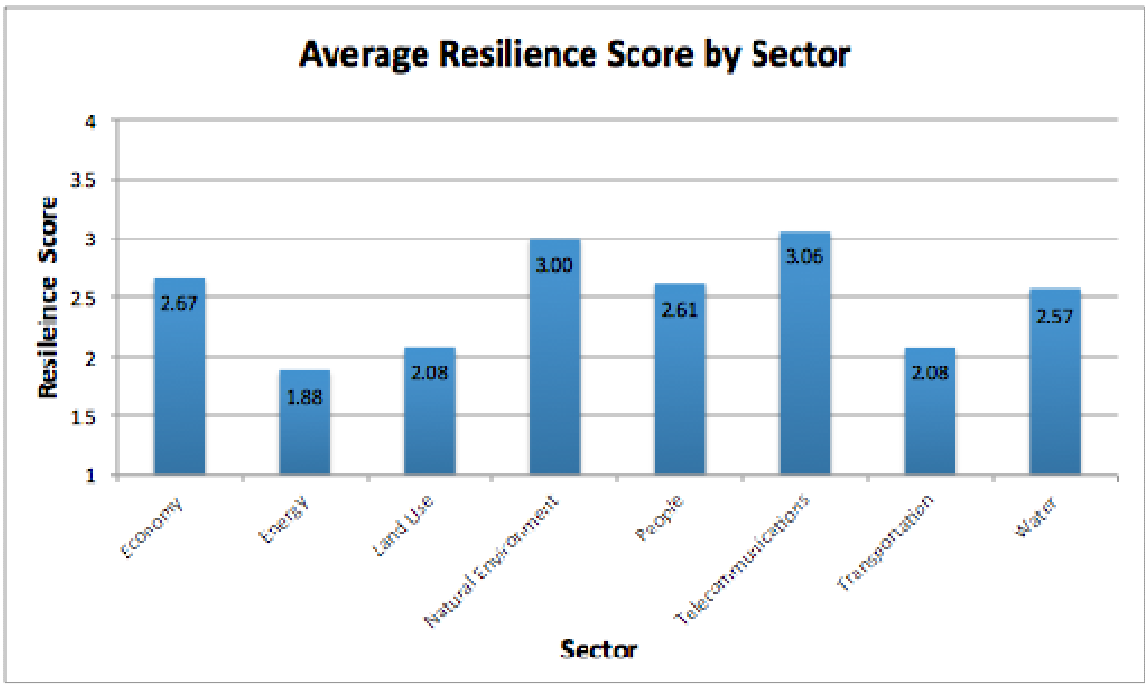

Figure 4: Comparison of the Average Resilience Scores of Each Sector. Range of resilience scores: minimum = 1.88 (Energy), maximum = 3.06 (Telecommunications). Overall average resilience score of all sectors combined = 2.58.

Of the ten questions in the economy sector interview, three were judged to be Not Relevant by interviewee from the Chamber of Commerce, leaving only seven questions as the basis to determine resilience in the Economy Sector. Two of the responses provided indicated low resilience and five responses showed high resilience.

Out of the two low resilience responses, one had a corresponding resilience score of 1 (lowest resilience), and the other had a resilience score of 2 (low resilience). The question which demonstrated lowest resilience inquired about the availability of funding for adaptive development projects that could also serve as recreation areas, such as flood retention areas along waterways that could also serve as parks. On the other hand, none of the questions elicited the maximum resilience score of 4, but there were numerous questions to which responses that satisfied the criteria for a resilience score of 3, which still indicates high resilience. "What financial capacity or credit risk is indicated by the city's bond ratings?" and "How flexible are planning processes for short-term and long-term responses" are examples of questions to which resilience score of 3 were provided.

The average resilience score of the seven questions answered was 2.67, which is slightly above 2.58, the total average resilience scores of all the sectors. The average of the importance scores was calculated to be 3.44, which was the second highest of all the sectors. This indicates that the seven questions asked were thought to be very important in evaluating the resilience of Worcester economy.

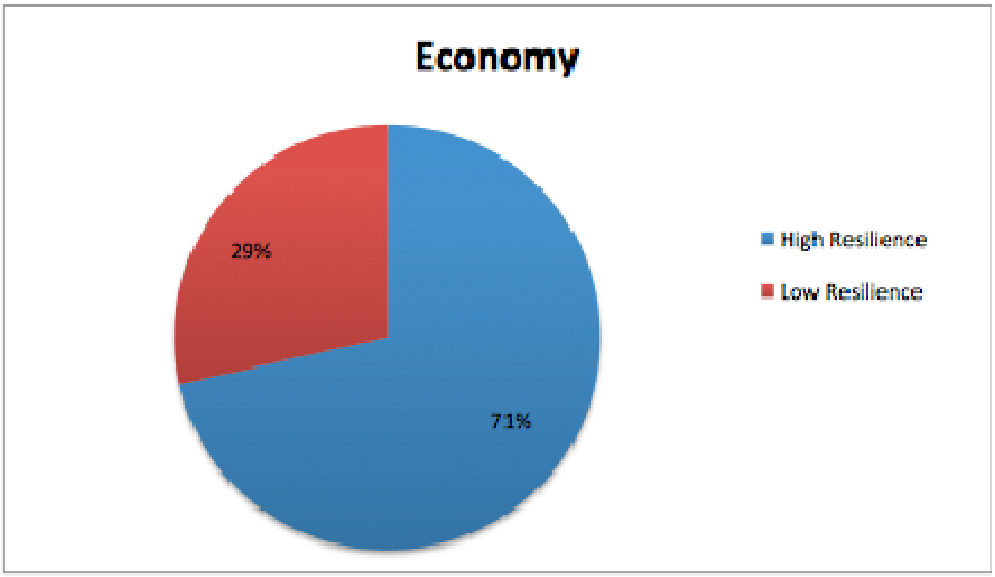

Figure 5: Breakdown of Responses for Economy. Area in red illustrates responses signifying low resilience and area in blue signifies responses demonstrating high resilience. Resilience scores of 1 and 2 were considered to be low resilience, while scores of 3 and 4 indicated high resilience. 71% of the responses demonstrated high resilience, with the remaining 29% indicative of low resilience.

Concerning the indicators that went along with the economy sector there was a total of 5 indicators 100% of them had data sets available. The average importance rating from 1-4 was a 3 and the average threshold based score was also a 3, indicating that there is a high threshold for Worcester's economy.

2. Energy

The set of questions for the Energy sector initially comprised nine questions, but interviewee John Odell, the Energy Manager of the City of Worcester, found one question to be irrelevant to assessing the resilience of Worcester's energy sector to climate stressors. As a result, resilience scores were provided for only eight questions. Two of the responses indicated high resilience and the remaining six were suggestive of low resilience.

Although two questions were marked as resilient, neither of them were assigned the maximum resilience score of 4, meaning that that both of them had a resilience score of 3. One example of a question answered with a resilience score of 3 was "To what extent have efforts been made to reduce energy demand?" signifying that moderate efforts had been made. For the six questions that emerged as low resilience, three were awarded resilience scores of two, and the remaining three were deemed to have the lowest resilience (Resilience score: 1). An example of a response indicative of a low resilience score was "Are there smart grid opportunities to manage demand?", to which the response provided was "No", thereby indicating lowest resilience.

This sector was found to have the lowest average resilience score at 1.88, a value far lower than the average of 2.58. Conversely, it ranked third highest in terms of

importance, with an importance score of 3.25, higher than the overall average importance score of 3.14.

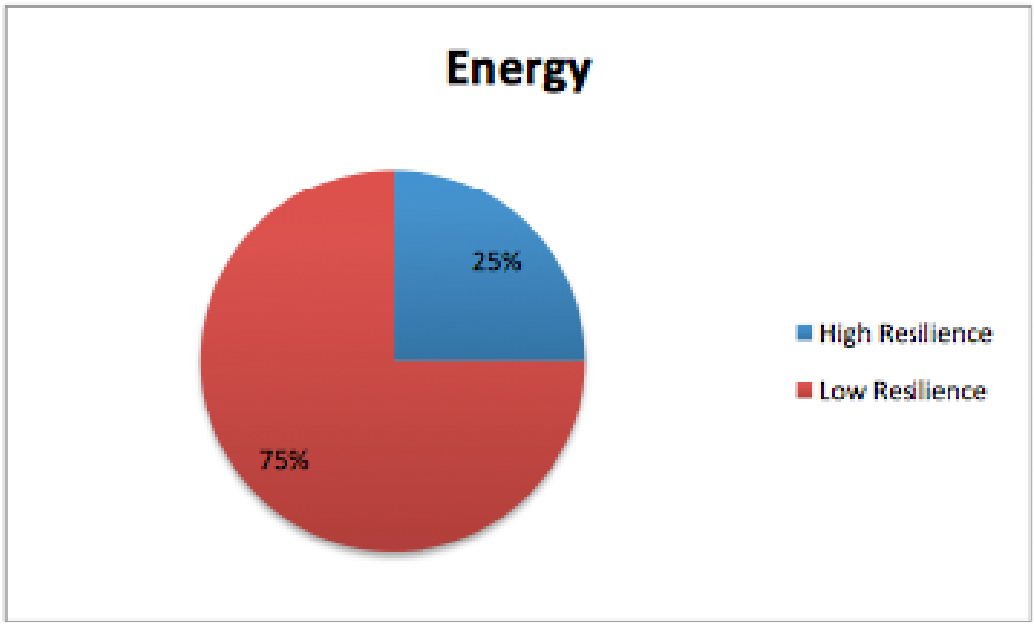

Figure 6: Breakdown of Responses for Energy. Area in red illustrates responses signifying low resilience and area in blue signifies responses demonstrating high resilience. Resilience scores of 1 and 2 were considered to be low resilience, while scores of 3 and 4 indicated high resilience. 75% of the responses indicated low resilience, 25% indicated high resilience.

The indicators that corresponded with the energy sector held an average importance of 2.77. With a total of 9 indicators there was 88.89% with ready data sets. The threshold based score is 2.75, giving a mediocre threshold level.

3. Land Use/Land Cover

The set of questions for the Energy sector initially consisted of seventeen questions, but one question was deemed irrelevant, meaning importance scores were provided for sixteen questions. However, the Acting City Planner was unable to provide answers (and therefore resilience scores) to a further six questions, meaning that resilience scores were provided for only ten questions. Four responses indicated high resilience, while the remaining six responses signified low resilience.

For responses indicating high resilience, none of the questions were answered with the maximum resilience score of 4, meaning that they all had a resilience score of 3. An example of one of the questions that was judged to have high resilience was "Does knowledge of historical land-use/ land-cover changes contribute to planner's understanding of climate stresses?", which was assigned a resilience score of 3. Conversely, for the six questions to which low resilience answers were provided, three of them had a resilience score of 1 (lowest resilience) and the other three had a resilience score of 2. Question 34, "Where developed land is located in areas vulnerable to extreme

events, are resilient retrofits being planned/implemented" was one of the questions that received a resilience score of 1 and thereby was indicative of low resilience.

This sector was found to have the lowest average resilience score at 1.88, a value far lower than the average of 2.58. Conversely, it ranked third highest in terms of importance, with an importance score of 3.25, higher than the overall average importance score of 3.14.

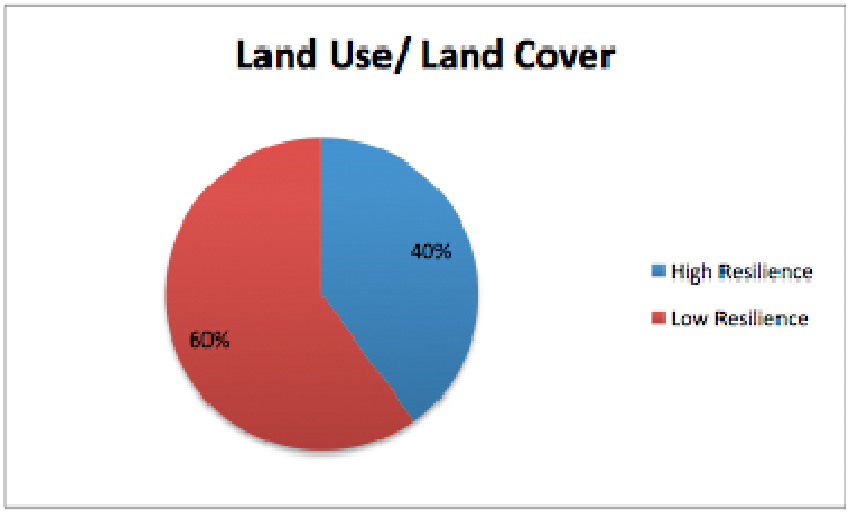

Figure 7: Breakdown of Responses for Land Use/ Land Cover. Area in red illustrates responses signifying low resilience and area in blue signifies responses demonstrating high resilience. Resilience scores of 1 and 2 were considered to be low resilience, while scores of 3 and 4 indicated high resilience. 60% of the responses indicated low resilience, while the remaining 40% signified high resilience.

Land use/ land cover has a total of 12 indicators of the 12 75% had data sets available. From the available data an average of 3.38 was given as an importance level. The threshold scores averaged to 2.29.

4. Natural Environment

The document CADMUS prepared for the natural environment sector contained 12 questions. Four questions were adjudged as Not Relevant by interviewee Rob Antonelli Jr., who serves as the Assistant Commissioner for Parks and Recreation for the City of Worcester, leaving a total of eight questions to assess resilience in this area.

Seven of these questions elicited responses indicating high resilience; one of those seven had the maximum resilience score of 4, while the other six had resilience scores of 3. The question that exhibited highest resilience was "Has the continuity of open or green spaces been assessed and addressed in planning efforts". Only one question displayed low resilience (resilience score of 2), and it inquired if the availability of environmental/ ecosystem goods and services would be at risk if affected by climatic changes.

Overall, the average of the eight relevant questions to which resilience scores were provided came out to be 3.00, the second highest of all eight sectors studied. The average of the importance scores also had a value of 3.00, which is fairly close to the total average of all the sectors combined, which was 3.14.

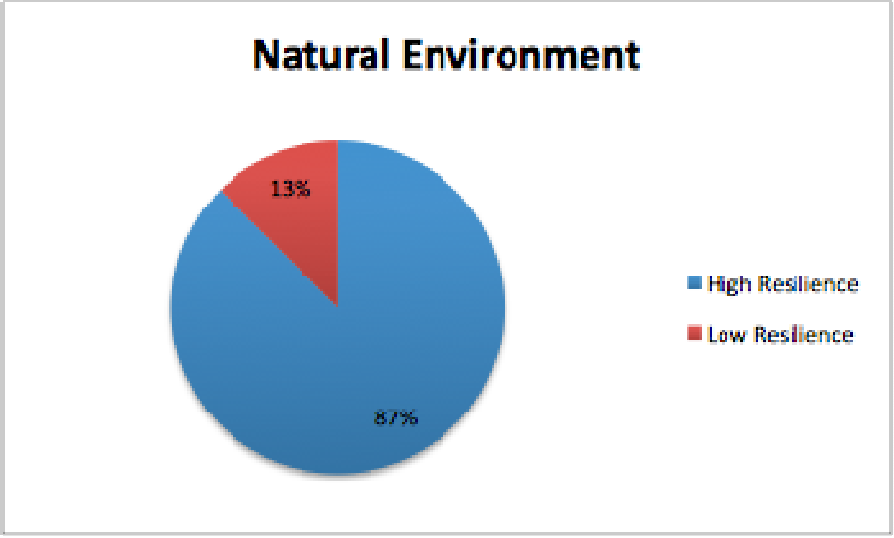

Figure 8: Breakdown of Responses for Natural Environment. Area in red illustrates responses signifying low resilience and area in blue signifies responses demonstrating high resilience. Resilience scores of 1 and 2 were considered to be low resilience, while scores of 3 and 4 indicated high resilience. 87% of the responses to questions in the natural environment sector indicated high resilience, while only 13% of the answers signified low resilience.

Natural environment has 10% of its 10 indicators having a data set. All the indicators suggested had an average importance as 1.75. The one data set gave a threshold of 4.

5. People

The set of questions for the People sector contained 22 questions, and every single question was found to be relevant to assessing this sector's resilience to climate stressors. The responses to 15 questions were indicative of high resilience, and 7 questions were suggestive of low resilience.

Of the highly resilient responses, only one of the fifteen was deemed worthy of the maximum resilience score of 4, with the other 14 being assigned a score of 3. The question to which the highest resilience score was given was "Are emergency response staff trained well to respond to large-scale extreme weather events?" On the other hand, for the seven questions categorized as low resilience, three questions were given a score of 1 and judged to have the lowest resilience, while the remaining four were given a score of 2. An example of a question that was answered with a corresponding resilience score of 1 was "Is there sufficient capacity in public health and emergency response systems for responding to extreme events?"

The results yielded an average resilience score of 2.61, which was extremely close to the overall average of all sectors combined (2.58). This sector produced the highest average importance scores with a grand total of 3.70, much higher than the overall average importance score of 3.14.

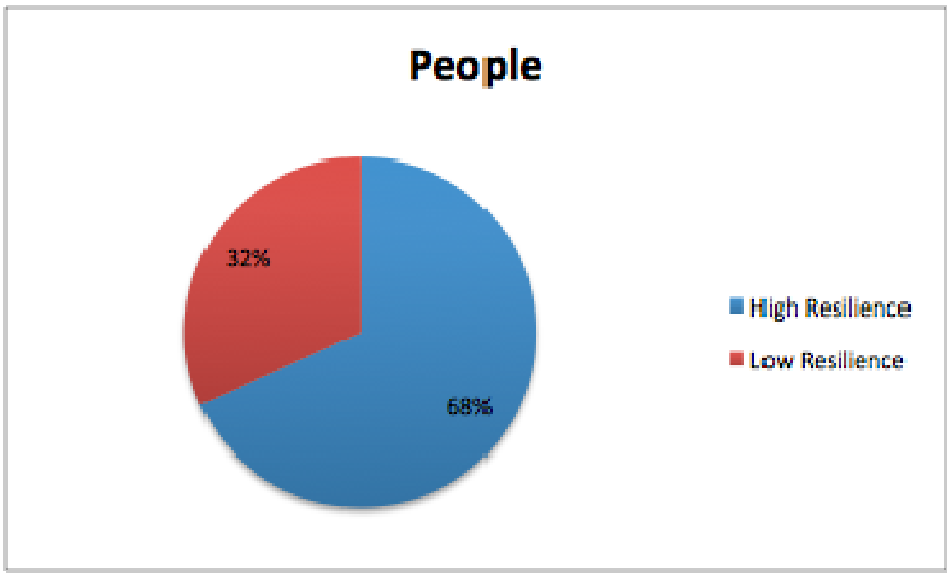

Figure 9: Breakdown of Responses for People. Area in red illustrates responses signifying low resilience and area in blue signifies responses demonstrating high resilience. Resilience scores of 1 and 2 were considered to be low resilience, while scores of 3 and 4 indicated high resilience. 68% of the responses suggested high resilience while the remaining 32% indicated low resilience.

Of the indicators for people 50% of the 18 had data sets that yielded a threshold score of 2.78. The importance was averaged to 2.75.

6. Telecommunications

CADMUS prepared a document comprising 17 questions pertaining to the telecommunications sector. David Clemons, Director of Emergency Communications for the City of Worcester deemed all the questions to be relevant, and was able to provide answers for all of the questions. 15 questions were found to have high resilience, and responses to 2 questions indicated low resilience.

For questions that suggested high resilience, 3 out of 15 had resilience scores of 4, which was the highest possible. This left 12 questions with resilience scores of 3. An example of a question that prompted a resilience score of 4 was "Do telecommunications systems have enough energy and water supply to handle extra load in the case of sudden natural disasters?" Conversely, only two questions indicated low resilience, neither of which had a resilience score of 1, the lowest possible resilience score. Question 77, "Are data centers located within or outside of the urban area?" was one of the two questions that scored a 2 for resilience.

The average resilience score was 3.06, the highest of all eight sectors studied. The average of the importance scores was 3.17, a value extremely close to the overall average of all the sectors combined, which was 3.14.

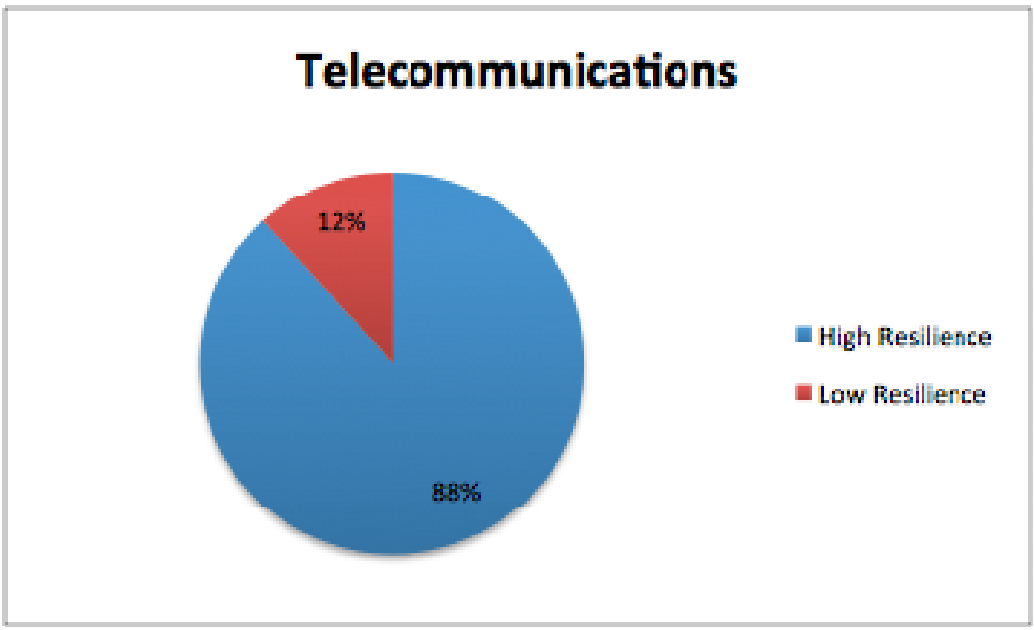

Figure 10: Breakdown of Responses for Telecommunications. Area in red illustrates responses signifying low resilience and area in blue signifies responses demonstrating high resilience. Resilience scores of 1 and 2 were considered to be low resilience, while scores of 3 and 4 indicated high resilience. 88% of the responses provided demonstrated high resilience, with only 12% of responses suggesting low resilience.

Telecommunications; 0 of the 4 indicators had data points so no Threshold was obtained. however the indicated stressors warranted an importance average of 3.67.

7. Transportation

Assessing the resilience of the transportation sector was initially supposed to be based on responses to nine questions, but two of the questions were thought to be irrelevant according to the interviewee. Out of seven questions answered, responses to 6 questions suggested low resilience and only 1 question demonstrated high resilience.

For questions indicative of low resilience, one question, regarding the length of time required to restore major freight rail transportation facilities after a failure, had a score of 1, indicating the lowest possible resilience. Responses to five other questions scored a 2 on the resilience scale of 1-4. The only question that demonstrated high resilience discussed the resistance of critical transportation facilities to potential impacts of climate change, which scored a 3.

The average resilience score was calculated based on the seven remaining questions, and was found to be 2.08, noticeably lower than the overall average of 2.58 for all sectors combined. The Transportation sector tied with the Land Use sector for having the second lowest average resilience score. The average importance score for the sector was 3.08, very close to the overall average of 3.14.

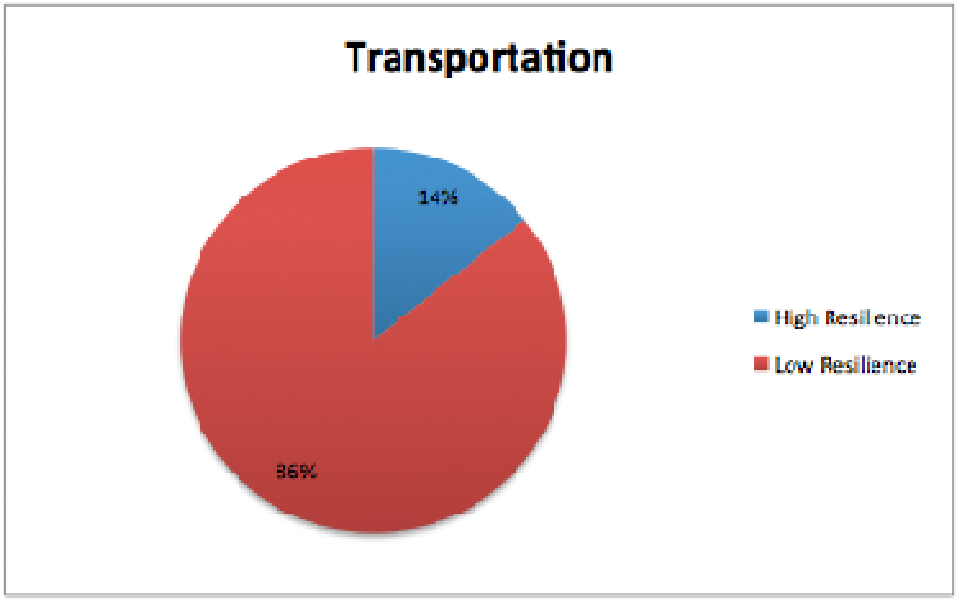

Figure 11: Breakdown of Responses for Transportation. Area in red illustrates responses signifying low resilience and area in blue signifies responses demonstrating high resilience. Resilience scores of 1 and 2 were considered to be low resilience, while scores of 3 and 4 indicated high resilience. Only 14% of the questions answered signified high resilience, while a monumental 86% of responses indicated low resilience.

There were 23 indicators suggested for Transportation of them 47.83% had data sets. That gave a threshold reading of 2.6. All 23 obtained an average importance score of 2 out of 4.

8. Water

A total of 17 questions were prepared in order to determine the resilience of Worcester's Water sector. Only one of the questions was thought to be not relevant, leaving 16 questions as the basis to determine average resilience in this sector. Out of the 16 questions answered, 12 responses signified high resilience and 4 responses implied low resilience.

For 12 of the responses indicating high resilience, eleven of them had a resilience score of 3, with only one question being attributed the maximum resilience score of 4. The question that scored highest on the resilience scale was about inventories of storms sewers and drains. On the other hand, for the four questions linked to low resilience, three of them had a resilience score of 1, and one question was given a score of 2. An example of a question to which the lowest resilience score was provided is, "To what extend do water supplies come from outside the metropolitan area?"

The average resilience score came out to be 2.57, almost identical to the overall average resilience score for all sectors combined, which was 2.58. This implies that the level of resilience for the Water sector is representative of the City of Worcester's resilience to climate stressors, on average. Moreover, this sector had an average importance score of 2.70, which was the lowest of all the eight sectors investigated.

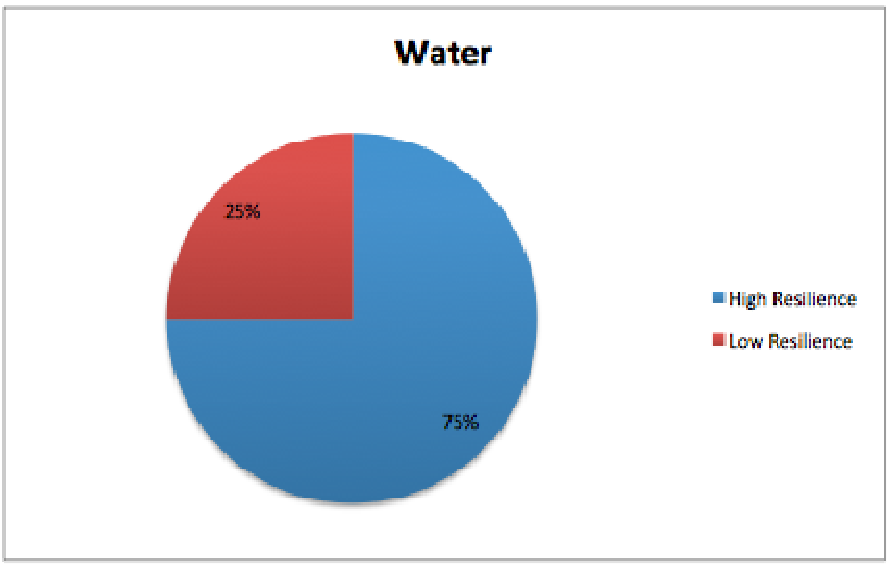

Figure 12: Breakdown of Responses for the Water. Area in red illustrates responses signifying low resilience and area in blue signifies responses demonstrating high resilience. Resilience scores of 1 and 2 were considered to be low resilience, while scores of 3 and 4 indicated high resilience. 75% of responses suggested high resilience, with the remaining 25% indicative of low resilience.

Water had 2 out of 4 indicators available for a threshold score and both scored a 4 out of 4. The average of the importance is ranked at 2.25.

Conclusions

Some important conclusions can be drawn from the data presented throughout the results section of this report. First, it can be deduced that Worcester as a city demonstrates moderate resilience to climate stressors. The average resilience score is 2.58, falling almost right in the middle of a score of 2 which indicates low resilience and a score of 3 which signifies high resilience. Second, of all the sectors studied, Telecommunications and Natural Environment show the highest resilience, while Energy, Land Use/Land Cover, and Transportation are the sectors that show the lowest resilience. These three sectors should be prioritized as prime target areas in need for improvement in any future climate action plans.

With the Threshold based scores obtained from the indicators it is hard to draw concrete conclusions due to the fact that some of the sectors did not all have data sets that could be scored. However from the results it can be seen that Worcester's scores float between 2 and 3, which indicates that current levels found in Worcester could be improved upon. The importance ratings show that the interviewees demonstrated some variance about what was important to the community. In some instances the indicators were not relevant to Worcester which suggests that for each city it is important to develop indicators that are widespread, but still have a focus on the city being assessed.

Like most projects, there were some limitations and challenges to assessing urban resilience in Worcester. Firstly, only one interviewee could be selected per sector, and it was sometimes challenging to decide whom to interview and who had the expertise most

suited to the set of questions. Furthermore, with only one interviewee, the results were subjective as they are based solely on one person's viewpoint. The Water sector was an exception because two people were interviewed with the same questionnaire within the water sector. In this sector, the responses differed considerably between the two experts on multiple.

The people who work for the city know a lot of information, and it is clear that it would be hard to find people with the same amount of information who are not City employees. It is important to also take this into account when looking at the data. For half of the sectors, there were less than 10 questions answered during the interviews. A few sectors had approximately 15 questions, and the largest number of questions answered was 22. In retrospect, the number of questions asked and responses provided was quite low, creating a relatively small sample size. Therefore, average resilience scores may not be an accurate reflection of the sector's resilience. The study could be improved if more questions were asked and answered, creating a larger sample size, which would lead to more accurate average values and allow for further data analysis.

There were also some issues that were found in regards to the questions that we asked the interviewees. The first being that with the yes or no questions they only have a score of resilience of either 1 or 3. However most questions had a score from 1 to 4 this change when it comes from a yes to no question is quite difficult to understand, because if the answer is yes why is the question not of the highest resilience (4) instead it become a mediocre score of 3. This causes the results to be skewed towards lower resilience. Second, the wording of certain questions confused interviewees, or made it difficult to understand what the question was asking because the wording did not match normal phenomenon. One example is Question 19 in the Energy department which reads: "How many minutes per year or hours per year do you have power outages?" The interviewee, John Odell, found that this question did not ask correctly about power outages, and he felt that the question should be restated to ask *when* the outages occur because the impact of a power outage in the middle of the night in the summer is not as severe as during the daytime in winter when the city is experiencing a freezing blizzard.

There was only one major obstacle that could not have been avoided, the unexpected Government shutdown. The shutdown lasted for sixteen days, a period during which no work could be done due to the fact that the EPA is a government funded program. As a result, interviews that were scheduled had to be cancelled as CADMUS was instructed not to work on the project, and thus they were unable to provide us with the set of questions to be used in the interviews.

With the indicators available, some thresholds could be scored. However the lack of data sets for some the indicators did not allow for scores to be found. This being the case the level of complete indicators was great to work with, but there was only one sector where each of the stressors had data sets that could be tested, and the rest were a piecemeal endeavor.

Finally, there has not yet been a formal report published yet on the other pilot study that was conducted in Washington, D.C. If and when a document on the DC study is made available, it would be beneficial to compare its results to those presented here from Worcester project.

Acknowledgements
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- David Clemons, Director of Emergency Communications & Emergency Management
- John Odell, Energy Manager
- Luba Zhaurova, Acting City Planner
- Rob Antonelli Jr., Assistant Commissioner of Parks & Recreation
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- Worcester Department of Public Health
- Worcester Regional Chamber of Commerce

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The Sustainable Knowledge Assessment

Shinobu Turner, Suram Edirisinghe

Abstract

Institutions of learning are increasingly making the push to incorporate sustainability into their curriculum. As the emphasis of campus sustainability increases these institutions need a tool the objectively indicates theirs students' sustainability knowledge, however such an assessment tool did not exist. Two students and two professors from the school of Environmental and Natural Resources of Ohio State University seeing the need for such an assessment tool created the Sustainable Knowledge Assessment. This tool consists of 16 questions focusing on the three domains of sustainability: economic, environmental, and social sustainability. This tool will not only enable colleges and universities across the nation to assess their students' knowledge on sustainability, but the information gathered from this assessment can also be used as an educational indicator. In essence it is one tool that would be used to assess one aspect of institutions overall sustainability practices. The Sustainable Knowledge Assessment was implemented at Clark University to assess the sustainability knowledge of two sub-populations: (1) full-time MBA Graduate School of Management (GSOM) students, and (2) a cohort of other students who were registered in one of four sustainability related courses that were "clustered" together during the fall 2013 semester.

Introduction

As colleges and universities across the nation increasingly emphasize sustainability, a systematic way of assessing students' knowledge on sustainability is needed (Zwickle et al 2013). Such a tool did not exist until two Ph.D candidates and two Professors at the School of Environmental and Natural Resources of Ohio State University created and refined an assessment tool to measure students' sustainability knowledge. This tool, otherwise known as the Sustainable Knowledge Assessment is comprised of 16 multiple choice questions focused around the three domains of sustainability: economic, environmental, and social sustainability. Although there are many ways to define sustainability these basic principles and concepts remain to be the standard: the continuing of economic growth, the observing and preserving of the natural environment, and society's social responsibility, all combined together to improve the lives of not only for our generation but also the lives of future generations to come (Zwickle et al 2013). This tool will allow these institutions to assess their students' individual understanding of sustainability.

Background

The development of the Sustainable Knowledge Assessment included a detailed process that included a series of refinement in order to narrow down the question pool to 16 questions (5 economic questions, 6 environmental questions, 5 social questions). After the creators of the tool narrowed the pool of question to those that they felt that fit well within the three domains and that they also felt were not too easy or too hard they held five rounds of focus groups (Zwickle et al 2013). Each focus group consisted of 3-7 faculty members and 2-12 graduate students within the School of Environmental and Natural Resources (Zwickle et al 2013). These focus groups provided feedback to the

developers on the appropriateness of each question. The focus group helped them eliminate some questions and create additional questions. A pilot implementation of the assessment followed that included additional faculty members, graduate students, and pre-selected undergraduate students (Zwickle et al 2013). Based on the results and the feedback that was given the assessment tool's pool of questions was reduced down to 30 questions (Zwickle et al 2013).

These 30 questions remained due to them covering core concepts within the three domains of sustainability, presented to be not too difficult or easy to answer, and there close to an even amount of questions spread within all three domains (Zwickle et al 2013). From there the questions were then formatted onto only software package called SurveyMonkey (Zwickle et al 2013). This assessment consisting of 30 questions was placed in front of a larger- sustainability survey, which was distributed randomly to 10,478 out of over 40,000 undergraduate students at OSU (Zwickle et al 2013). The response received show that 2,019 students started the assessment, and of that 2,019 students 1,389 students completed all 30 assessment questions (Zwickle et al 2013). The creators of the assessment learned that having a lengthy assessment proved to be a great disadvantage seeing the large dropout rates of participation within the assessment (Zwickle et al 2013). The way the assessment was formatted was 10 question per page, show that the assessment was three pages long (Zwickle et al 2013). The participation within the assessment significantly dropped each time participates were presented with another page of the assessment to fulfill (Zwickle et al 2013). Using this crucial information that was provided from this round of assessments that was distributed to a larger audience, the makers of the assessment decided to significantly reduce the amount of questions that would be presented within the assessment. The assessment questions went from a pool of 30 to 16 questions (Zwickle et al 2013).

Using the prior data that was collected of the 1,389 students who completed all 30 question within the assessment, the assessment makers focused only on the 16 questions that they chose.The makers of the assessments only focused on the 16 questions that they narrowed down from 30. It was there that they were able to draw conclusions of how wells students did on the assessment. From there the assessment developer found that undergraduate students at OSU scored on average a 69% on their overall understanding of sustainability (Zwickle et al 2013). They also found that upperclassmen performed better on the assessment than that of underclassmen. Another piece of information they found as a result of compiling and comparing results, is that a student's major did not have an effect on their performance in exceling in one domain more than other domain, and furthermore performing better than other students who do have a focus within these particular domains of sustainability. These results came to a surprise to the creators of the assessment. Overall the testing and refining of the assessment tool enabled the makers of the Sustainable Knowledge Assessment to understand which and how many questions are appropriate to include within the tool. The results compiled enabled them to see how well students performed as a whole, by class rank, and by major. The results proved to be very helpful for the creators of the assessment for it allowed them how fair questions are to answer. This assessment was also used at University of Maryland, and is currently being used at Colorado State University and the University of Mississippi (Zwickle and Stewart 2013).

The Sustainable Knowledge Assessment, as it applies to Clark University, will assess full-time Graduate School of Management students' knowledge on sustainability. The Graduate School of Management (GSOM) has gained both national and international recognition for their focus on the environment. In The Aspen Institute's 2011-2012 edition of *Beyond Grey Pinstripes*, which is noted for recognizing MBA programs that integrate social, environmental and ethical issues within their curriculum, GSOM is ranked 86th out of the top 100 schools worldwide (Connect 2012). The organization goes even further by explaining that the MBA program here at Clark is a leader in helping prepare students for social and environmental stewardship. GSOM has also been recognized by *Entrepreneur* and *the Princeton Review* as one of the top 16 institutions where MBA students can receive education in "Green Business" fields (Clark News Hub 2011). The Graduate School of Management is also recognized to have contributed to Clark University being ranked 17th on the "Coolest Schools" list in *Sierra* magazine (2012). Also, GSOM has received both nationally and internationally for incorporating sustainability into its curriculum (Clark GSOM Report 2012). The recognition that the GSOM has received within the recent years has led Shinobu Turner and Suram Edirisinghe to focus this assessment tool on this particular group of students. This project will focus on full-time MBA Graduates School of Management students' knowledge, and more importantly, after compiling the results this project will focus on comparing students' performances based on what concentration they are doing. We believe that students' whose concentrations are more environmentally focused will perform better on the assessment to those who are not.

Process

This project involved multiple steps. The first step involved deciding upon a sub-population of Clark students to take the assessment. At the beginning of the semester, we were discouraged from trying to get administrative permission to send the assessment out to all Clark students because requests to survey the student body are often denied. We decided on two sub-groups. 55 MBA GSOM students were chosen due to the recognition as indicate in the previous section. The second group we targeted was a group of 56 students enrolled in sustainability related courses that were coordinated as part of the University's LEEP cluster program. This four courses included in this cluster included Health & the Urban Environment, Land &Water Resources, the Sustainable University, and Urban Ecology. The student enrolled in these courses included some graduate students, upperclassmen and underclassmen enabling a comparison of different levels of education.

The second step included determining whether to use all 16 questions that the creators of the assessment tool used. We decided to omit one question because it was similar to another question and we also wanted an even amount of questions within each domain (environmental, economic, and social). We also decided to add three demographic questions so that participants identified their class/ concentration, their class rank, and gender. This brought the total number of questions to 18.

The third step involves setting up the online system so students could access and answer the questions. We used SurveyMonkey to implement the survey because it is accessible and kept the identity of our participants anonymous. Using SurveyMonkey our group decided to create to separate test to given to the two different groups of students.

The reason why we administered two different tests was due to make the demographic questions differently in order to use the data correctly and accurately. We thought it would make it easier for us to compile the results as it pertained to both separate groups.

The fourth step was to get approval for the assessment through Clark's Institutional Review Board (IRB). We submitted an IRB proposal that included an anonymous consent form which is an essential component of our project (without IRB approval we would not have been able to administer the assessment). The IRB approval process took about a month, so there was a point where we were concerned about the timing. Once we got IRB approval, Shinobu Turner worked with GSOM staff to distribute the assessment to full-time MBA GSOM students, and Suram Edirisinghe worked with the faculty of the four LEEP cluster courses to distribute the assessment.

The next step included closing the assessment and administering a 'thank you' email with the attached answers to the questions. The results from the assessment were then compiled and graphed.

Results

Leep Cluster Courses:

The overall the participation from the LEEP Cluster Courses showed that 34 out of the 56 students participated in the assessment. Out of the 34 students who participated 25 of them are female and 9 of them are male. Figures one and two show the overall response separated by class rank and LEEP Cluster Course (Figure 1) . As shown in the figures section, most of the students who participated are upperclass with 32% of the participation coming from Juniors. Also, the most who participation based on courses are the Health & the Urban Environment class and the Sustainble University class, both garnering a 31% participation. Figure 3 demonstrates students' overall performance, showing that students on the whole received 79% on the assessment. Figures 4, 5 and 6 show how students performed within each sustainability domain. The highest score garnered was within the environmental domain with a score of 79% and the lowest score garnered by students was within the economic domain with a score of 66%. These results show that students overall have a better understanding of environmental sustainability, and possessed less knowledge within economic and social domains of sustainability. Figures 7 and 8 show how students performed by class rank. Upperclassmen garnered a higher score than that of underclassmen. Upperclassmen show to have score 10% higher than that of underclassmen. The results gained within these two figures coincides with the results that the creators of the assessment found when they compared the results of upperclassmen to that of underclassmen.

GSOM students:

29 GSOM students responded to the invitation and completed the survey (5% response rate). Out of the 29 respondents, 13 are female and 16 are male.
Figure 9 and 10 shows GSOM respondents by years and concentrations and Figure 11 shows the overall response, GSOM students' overall performance on the whole received 59% corrected points and 41% missed, which is considered a weaker performance to that of the testing group of students (LEEP students). Figure 11 to 13 shows how GSOM students' performance within each sustainability domain. The highest score garnered was within the social domain with a score of 64% and the lowest score garnered by GSOM

students was within the environmental domain with a score of 51%. The results show that GSOM students have a better understanding of social sustainability, less knowledge within environmental domain of sustainability. Most respondents are from finance and accounting (32%, see figure 10) despite of our original assumptions that social and sustainable global business students would participate more in the assessment.

Discussion and Conclusions

The results gathered from the GSOM students, showed that there was no clear group who did profoundly better on the assessment than that of others group, when comparing students based on their concentration. Although we originally thought that students from the Social Change and the Sustainable Global Business concentrations might have a higher level of sustainability knowledge, the results of 29 students who responded to the assessment did not show such results. Despite the positive recognition Clark's MBA Green Business program has received recently by *Sierra Magazine,* which provides indispensable guidance for those who care about environment, this assessment does not show a higher level of sustainability knowledge among students within these programs. However, our results did show a variation between underclassmen (freshman and sophomores) and upperclassmen (juniors, seniors) and graduate students. This information coincides with the results gathered from the Ohio State University students who participated in the assessment. Therefore, the results suggest that upperclassmen having been accustomed to the college setting for a longer period of time, and having more opportunities of taking classes within these settings has allowed them to obtain a greater amount of knowledge within sustainability. Moreover, the result from the GSOM students' data suggests that they are more sustainably knowledgeable on socially oriented subjects, whereas LEEP Cluster students are more knowledgeable on subjects that are centered on the environment.

More over, the result from the GSOM students' data suggests that they are more sustainably knowledgeable on socially oriented subjects. On the other hand, LEEP Cluster students are more knowledgeable on economic oriented subjects. Although our main purpose was not simply comparing the results among these three groups of students (underclassmen, upperclassmen and graduate), this was unique to see the different outcomes by the level of year.

The application of this assessment for this project was limited in that only a total of 63 Clark students completed the assessment. This assessment could be implemented to a larger sample of students to gain more information. Also, this tool has potential to assess changes in sustainability knowledge over time and among different sub-samples of students in different programs and different universities. Although, the assessment was conducted with a few sample of the Clark students, LEEP students show the similar result with Ohio States' respondents as they also scored high on the environmental and economic questions, and lower on the social questions (See Figures 4-6).

Speaking of the measurement method of sustainability, the Association for the Advancement of Sustainability in Higher Education (AASHE) has developed and disseminated the Sustainability Tracking, Assessment, and Rating System (STARS). This rating system, adopted by over 200 institutions of higher education, awards points based on different sustainability-related practices. Ohio State University provided the data after conducting the assessment to get a STARS credit. It helps to understand about the level

of their sustainability education initiatives by being evaluated by AASHE. Apparently, the assessment is not appropriate for evaluating individual courses; rather it would be only appropriate to get some ideas to design individual courses for instructors who teach sustainability courses. As most Colleges and Universities are focus on green growth and sustainable development, Clark is also considering the STARS Program towards Clark's ongoing sustainability efforts.

The tool has potential to assess the changes in sustainability knowledge over time, among different sub-samples of students in different programs within Clark University. Given Clark's commitment to sustainable initiatives throughout the campus, this assessment could be helpful in assessing all students within the university about their knowledge on sustainability. More importantly the Sustainable Knowledge Assessment could be used to enhance and support the Clark's commitment in becoming a more sustainable university.

We came across several challenges this semester as we worked on this project, and overall we wish we could have had more time. First, we had a difficult time getting approval from Clark's Institutional Review Board, which must approve all research or surveys on human subjects. This was a time consuming process that created frustration for our team. If we had been able to get IRB approval quicker, we would have benefited from more time to implement and analyze the assessment. We could have spent more time recruiting students to participate and we could have spent more time analyzing the results. In fact, the assessment can't provide a complete assessment of sustainable knowledge due to the limited assessment tools. These 15 questions are very limited. These are not enough assessment tools to assess students' general knowledge of sustainability. Students might know a lot about sustainability and just not know the answers to those 15 questions. Although the assessment hasn't captured all the students' sustainable knowledge, our project shows a way to engage in systematic comparisons by years and concentrations of students. To further develop our assessment, we should refine and add questions to increase the respond rate as well as establishing a baseline to assess students' knowledge in the subject from data. Furthermore, if AASHE is interested, the rating system might be going to be scaled up by correcting dates from various institutions. Another idea is that there is a potential to use this type of assessment outside of academia. For example, the assessment can be taken at corporations to define their "green business" as well as understanding of employees' awareness of sustainability.

To conclude, it was important to give students a time to understand the contents of the origin of the assessment prior to make a clearer message to audience or reader. Due to the time consuming process, we did not obtain the necessary numbers for analysis assumptions. But, it was a meaningful experience to see students' sustainable knowledge in general include testing our own knowledge. Sustainability is much more complex than we can hope to know and due to the nature of sustainability issues facing the world, this type of assessment should be evolved, modified and continually built upon. Sustainability knowledge can't be defined statically because sustainability concerns change frequently along with the technology developments and climate changes as we learned in our class and from assigned readings. In the future, we anticipate and hope that we can utilize the assessment tool for sustainable development goals on Clark University and think further about how we conceptualize and measure sustainability knowledge not only for students but also for faculties, staffs and Clark community.

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Figures and Appendix:

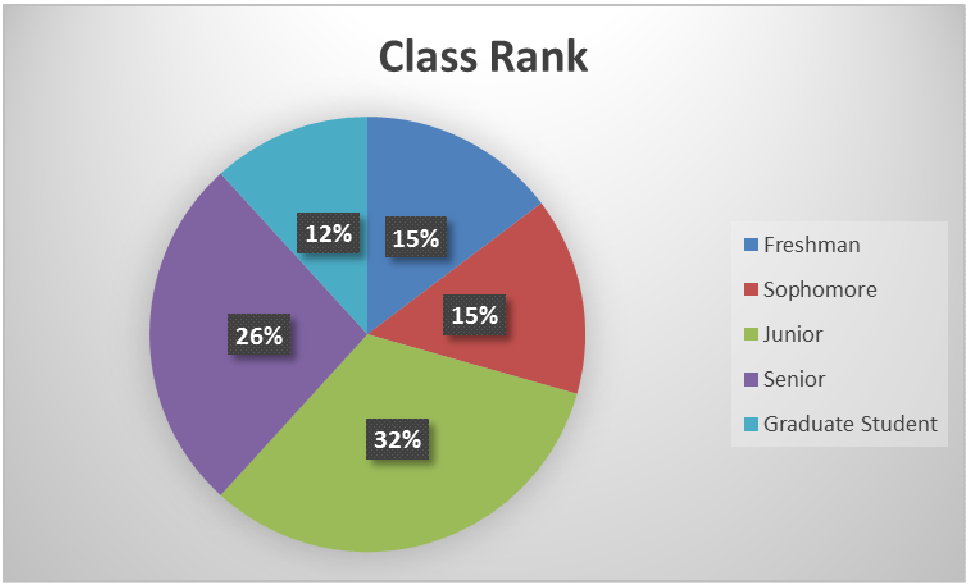

Figure1. Breakdown of how many students from the LEEP Cluster Courses participated in the assessment by class rank.

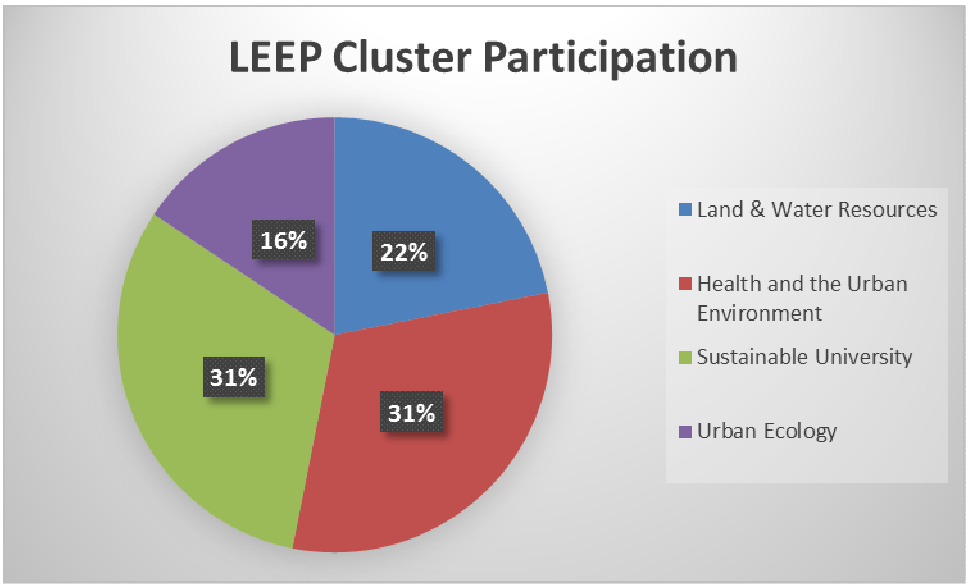

Figure 2. Breakdown of how many LEEP Cluster students participated in the assessment based on what class they are in.

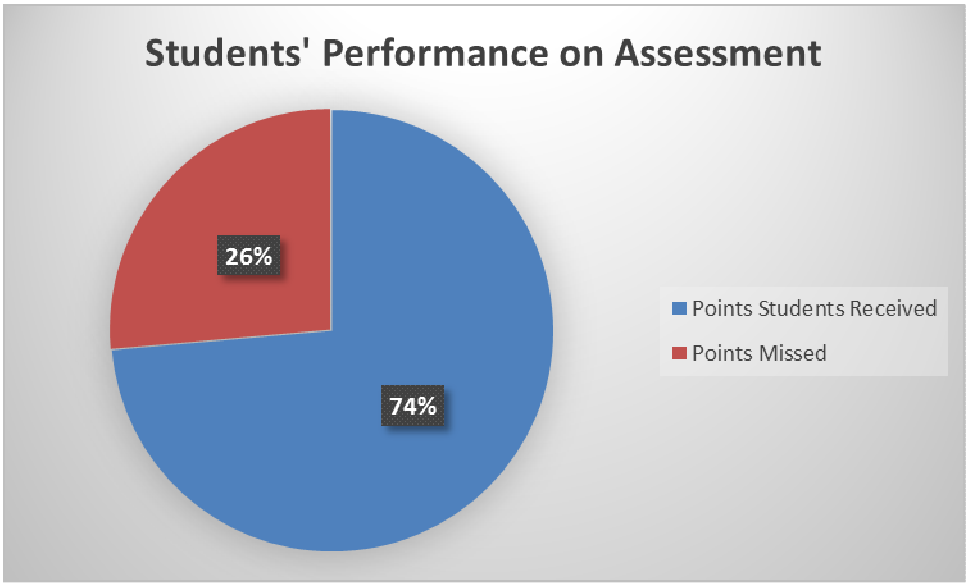

Figure 3. Overall average that LEEP Cluster students garnered.

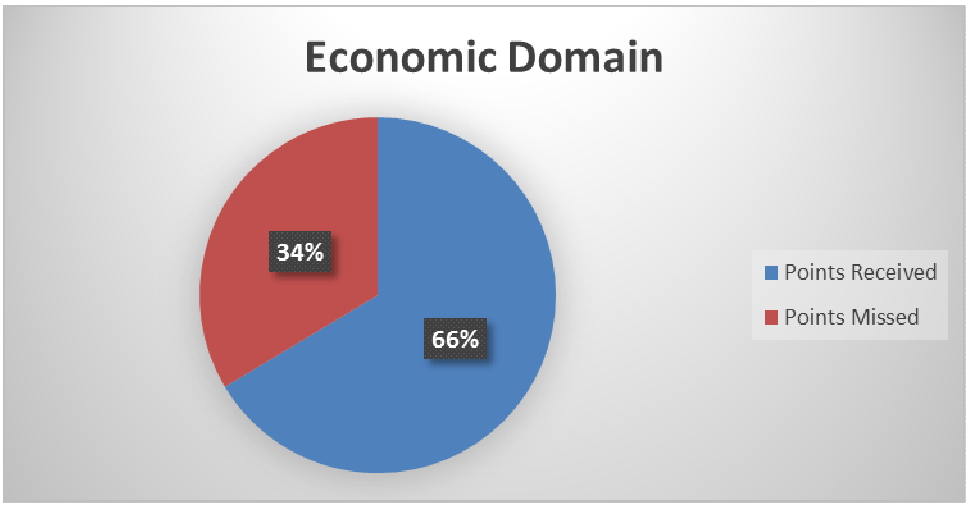

Figure 4. Overall average score LEEP Cluster students received from answering all the economic domain questions.

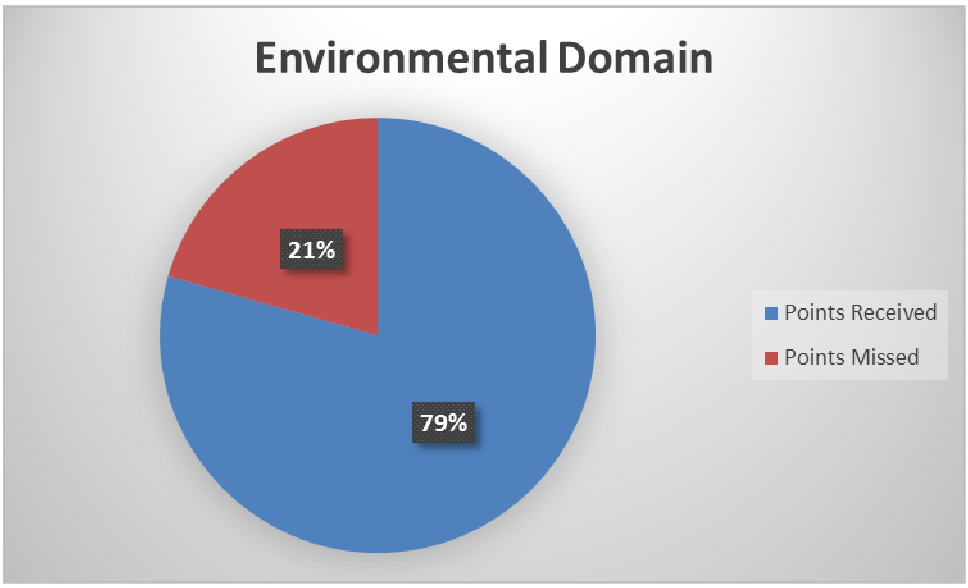

Figure 5. Overall average score LEEP Cluster students gained when answering all the environmenal domain questions.

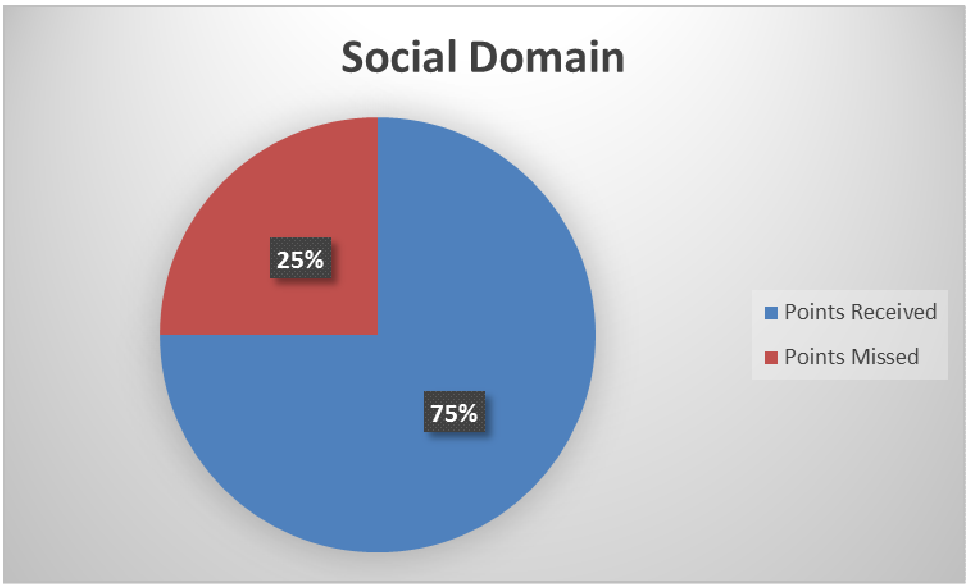

Figure 6. Overall average score LEEP Cluster students garnered by answering all the social domain questions.

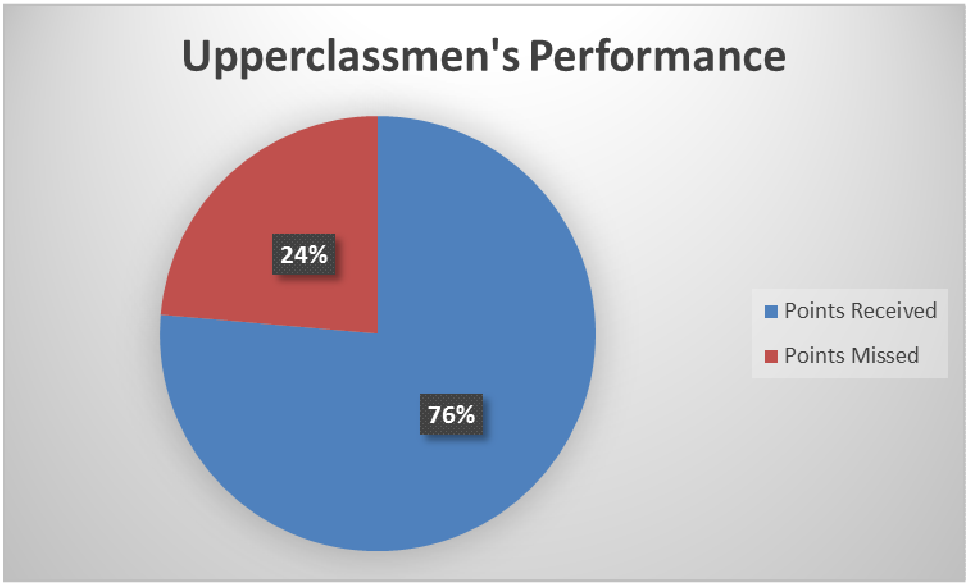

Figure 7. Overall average score upperclassmen within the LEEP Cluster Courses received on the assessment.

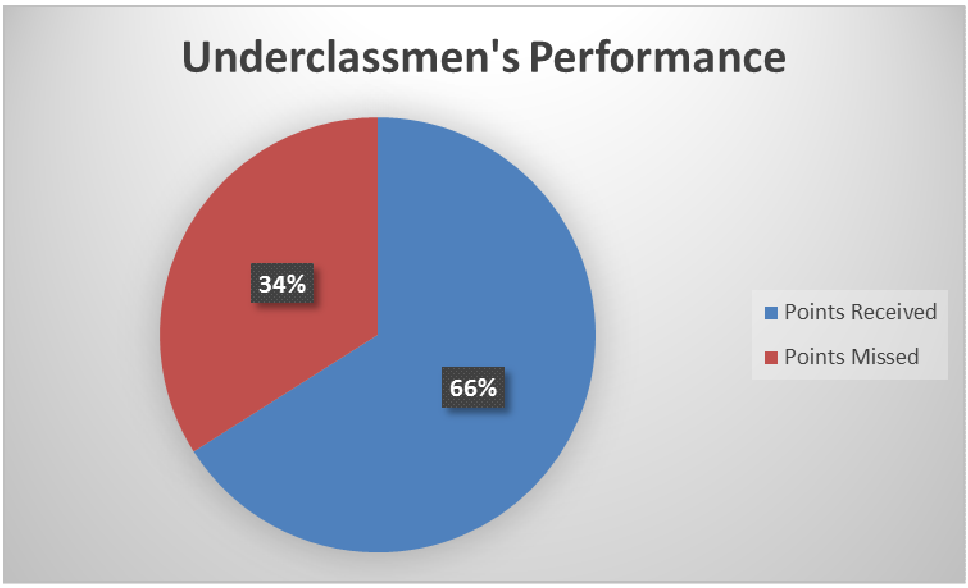

Figure 8. Overall average score underclassmen within the LEEP Cluster Courses received on the assessment.

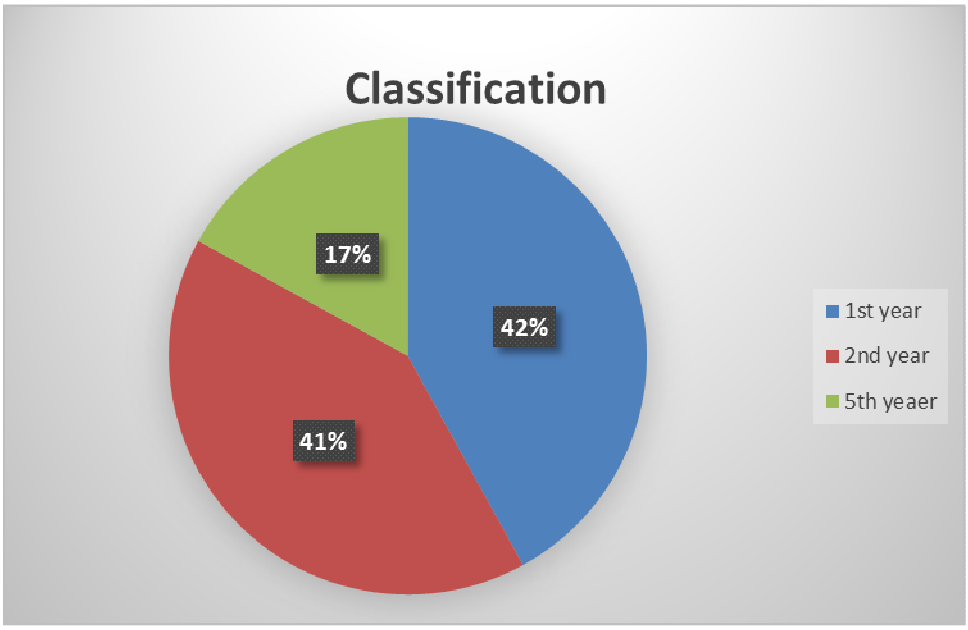

Figure 9. Classification of GSOM students

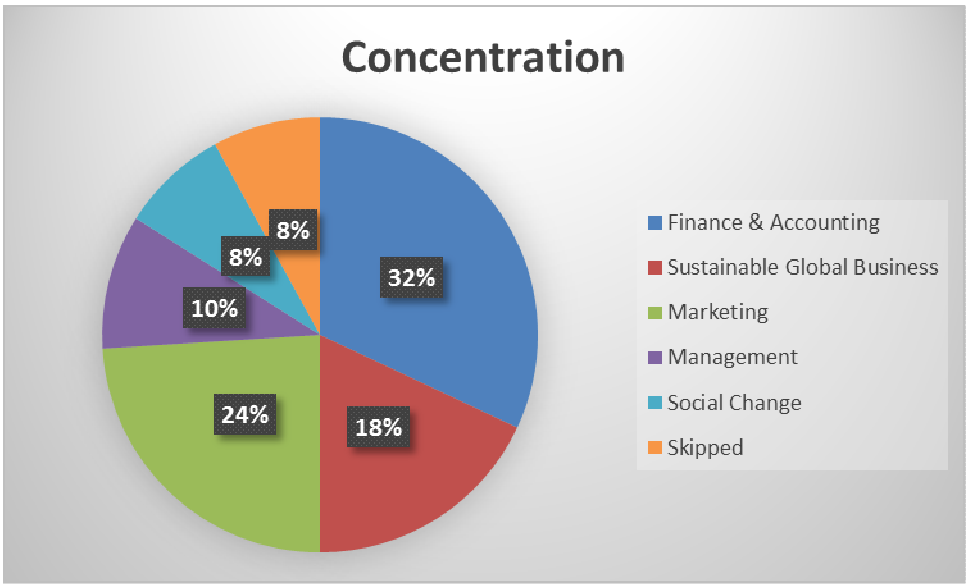

Figure10. Breakdown of GSOM respondents' concentrations

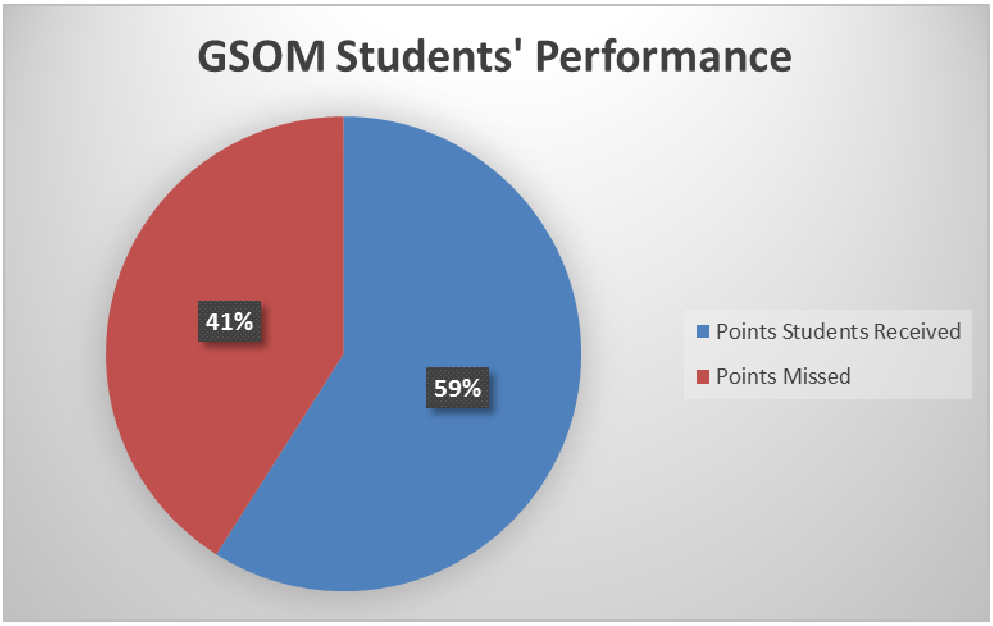

Figure11. Overall average that GSOM students garnered

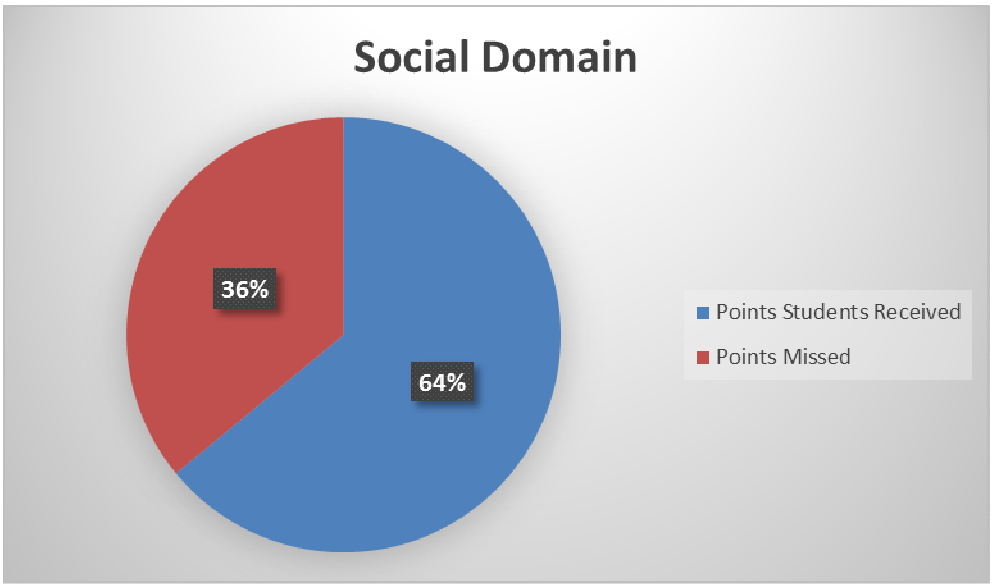

Figure 12. Result from social domain questions from 6 through 10 (See Appendix)

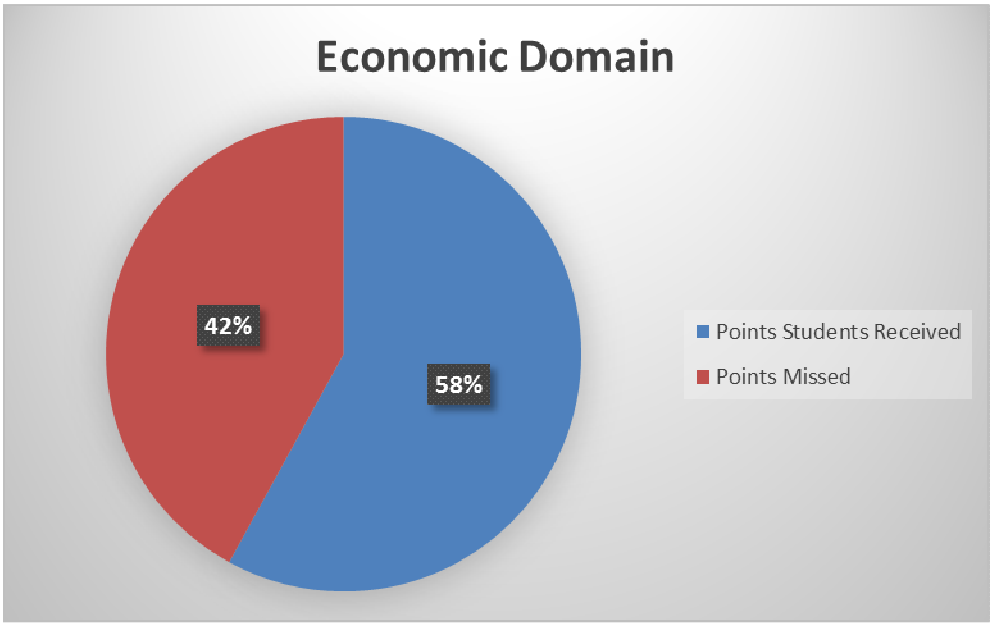

Figure 13. Result from economic domain questions from 11 through 15 (See Appendix)

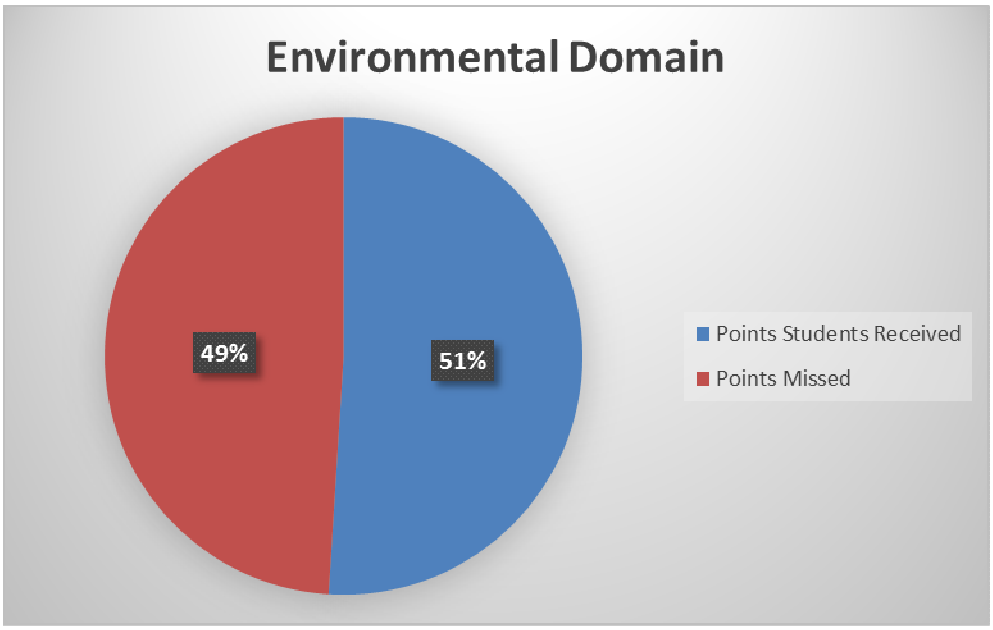

Figure 14. Result from Environmental Domain questions 1 through 5 (See Appendix)

Appendix: This appendix shows the 15 questions that were used in the assessment. The bolded lines are the correct answers to the listed questions.

Sustainable Knowledge Assessment Answers

1. What is the most common cause of pollution of streams and rivers?
    a. Dumping of garbage by cities
    b. Surface water running off yards, city streets, paved lots, and farm fields
    c. Litter near streams and rivers
    d. Waste dumped by factories
    e. Don't know

2. What is the name of the primary federal agency that oversees environmental regulation?
    a. Environmental Protection Agency (the EPA)
    b. Department of Health, Environment, and Safety (the DHES)
    c. National Environment Agency (the NEA)
    d. Federal Pollution Control Agency (the FPCA)
    e. Don't know

3. What is the primary benefit of wetlands?
    a. Promote flooding
    b. Clean the water before it enters lakes, streams, rivers, or oceans
    c. Keep the number of undesirable plants and animals low
    d. Provide good sites for landfills
    e. Don't know

4. Which of the following is an example of sustainable forest management?
    a. Setting aside forests to be off limits to the public
    b. Never harvesting more than what the forest produces in new growth
    c. Producing lumber for nearby communities to build affordable housing
    d. Putting the local communities in charge of forest resources
    e. Don't know

5. In the U.S., what do we currently do with the nuclear waste generated by nuclear power plants?
    a. Use it as nuclear fuel
    b. Sell it to other countries
    c. Dump it in landfills
    d. Store and monitor the waste
    e. Don't know

6. Which of the following is the most commonly used definition of sustainable development?
    a. Creating a government welfare system that ensures universal access to education, health care, and social services
    b. Meeting the needs of the present without compromising the ability of future generations to meet their own needs
    c. Setting aside resources for preservation, never to be used
    d. Building a neighborhood that is both socio- demographically and economically diverse
    e. Don't know

7. The wealthiest 20% of people in the U.S. own approximately what percent of the nation's privately held wealth?

a. 20%
b. 35%
c. 50%
d. 85%
e. Don't know

8. Over the past 3 decades, what has happened to the difference between the wealth of the richest and poorest Americans?
   a. The difference has increased
   b. The difference has stayed about the same
   c. The difference has decreased
   d. Don't know

9. Higher levels of education generally lead to…
   a. Lower levels of voter turnout
   b. Greater annual earnings
   c. Larger family size
   d. Higher self esteem
   e. Don't know

10. Which of the following populations has the highest rate of growth?
    a. North America
    b. Europe
    c. China
    d. Africa
    e. Don't know

11. Which of the following countries has now passed the U.S. as the biggest emitter of the greenhouse gas carbon dioxide?
    a. China
    b. Sweden
    c. Brazil
    d. Japan
    e. Don't know

12. Many economists argue that electricity prices in the U.S. are too low because…
    a. They do not reflect the costs of pollution from generating the electricity.
    b. Too many suppliers go out business
    c. Electric companies have a monopoly in their services area
    d. Consumers spend only a small part of their income on energy
    e. Don't know

13. Which of the following is a leading cause of the depletion of fish stocks in the Atlantic Ocean?
    a. Fishermen seeking to maximize their catch
    b. Reduced fish fertility due to genetic hybridization
    c. Ocean pollution
    d. Don't know

14. Which of the following is the most commonly used definition of economic sustainability?
    a. Maximizing the share price of a company's stock
    b. Long term profitability
    c. When costs equal revenue
    d. Continually expanding market share

e. Don’t know

15. Which of the following is the primary reason that gasoline prices have risen over the last several decades in the U.S.?
    a. Growing percentage of gas stations owned by larger corporations
    b. Increasing oil discoveries overseas
    c. Higher rates of state and federal gasoline tax
    d. Increasing global demand for oil
    e. Don’t know