Green Roofing at The University of Michigan
Final Report

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December 12, 2012

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Executive Summary

Without a focused movement toward sustainable functions/operations within the academic organization and its infrastructure, the University of Michigan will struggle to meet the 2025 Sustainability Goals declared by Mary Sue Coleman. Green roofing will support this community wide movement and promote additional benefits, while simultaneously allowing us to promote the living-learning laboratory of U-M's campus, and uphold our title as the 'Leaders and the Best'.

As one of the world's largest research institutions, the University of Michigan is a crucial player in setting the precedent for sustainable practices. Situated in the urban community of Ann Arbor, the University of Michigan provides a unique proxy for sustainable development of cities and campuses. U-M will be able to set an example of sustainable construction practices by including green roofs on newly constructed or renovated buildings on campus. This economically feasible investment opportunity would confirm the university's commitment to sustainable practices.

Green roofs provide economic incentives, environmental benefits, and enhance community health. Economic incentives include conserving building energy conservation between 15% and 30% resulting from increased insulation, and increasing a roof's longevity by two to three times that of conventional roofs. Green roofs also provide environmental benefits including decreased rainwater runoff by 50% to 85%, lowering urban heat index, and reducing pollution (Wilkinson & Reed). In addition, psychological and physiological health demands access to nature, and green roofs will act as a portal in urban communities to support this need. The aforementioned benefits of green roofing will help U-M to reach its Sustainability Goals by 2025 but also will contribute to a healthier and more environmentally friendly community.

Our recommendations are based on a semester wide compilation of findings, which included secondary research, case studies, interviews, site visits, and collaboration with the A3C architectural firm. Moreover, we held professional meetings with various deans and stakeholders of multiple schools at U-M, including the School of Nursing, Ross School of Business, Ford School of Public Policy, Graham Environmental Sustainability Institute, the School of Music, Theater and Dance, the School of Social Work, and the School of Public Health.

After meeting with the stakeholders mentioned above, our findings confirm that all have interest and enthusiasm for the implementation of green roofs. The main barriers include the initial investment, the required weight load, and the maintenance costs. In addition, deans indicated that they were concerned about how the cost savings would be absorbed by their building, and if the university's central administration would be capable of providing initial capital for schools with budget constraints. Limitations in creating accessible green roofs include U-M safety codes and liability issues. However, so far, current green roofs on the U-M campus have only resulted in positive feedback from students, faculty and visitors to the campus, with minimal burden to facilities operators and upkeep costs. Our efforts and findings throughout the

semester support our recommendation that greening campus roofs should become a priority to university construction plans and initial subsidization should be considered

Introduction and Background Information

Global climate change is recognized amongst many intellectuals across the nation. This is reflected in current research studying its affect on environmental stability (1). Specifically, in Ann Arbor Michigan, the University of Michigan provides a unique microcosm where students and faculty put forth an effort to initiate sustainable practices on campus. Student groups responsible for fostering the 'green' paradigm include the Students for Sustainable Initiative (SSI), the Office of Campus Sustainability, the Graham Environmental Sustainability Institute, and lastly the Environmental Sustainability Executive Council with Mary Sue Coleman acting as Chairwoman. Together these organizations and committees embody the collaborative framework necessary to initiate serious institutional changes to how the university approaches campus sustainability. With our president at the forefront of the school's approach to environmental issues, the University of Michigan has set sustainability goals for 2025 under four broad categories: climate action, waste prevention, healthy environments, and community awareness. Specific tangible goals that greening our campus roofs can impact include: minimizing runoff from impervious surfaces, outperforming uncontrolled surfaces by 30%, reducing greenhouse gas (GHG) emissions by 25% below their 2006 levels, as well as purchasing 20% of food within the Sustainability Food Guidelines.

In many cities and universities around the world, the concept of green roofing has been met with increased optimism as research continues to show the multitude of benefits that these seemingly decorative roofs produce. An integral step towards assessing the feasibility of greening a roof on any particular building is a cost-benefit analysis, primarily examining the benefits of insulation. Additional benefits embody the more intangible effects of green roofs that many staff, students, and faculty at the University of Michigan may not initially grasp. The unknown benefits associated with green roofs illustrate just how intricate their implementation truly is. Installing a green roof, as opposed to a conventional roof, will provide the following:

1. a reduction in energy payments (via insulation) (3)
2. improved air quality via lowering urban heat index and sequestering carbon dioxide (6)
3. infrastructural longevity of roof lifespan (two to three times greater) (3)
4. decreased building rainwater runoff, providing tax credits in certain cities (3)
5. facilitated post-surgery recovery time (7)
6. increased productivity and decreased stress levels of participants (4)(5)
7. promote community cohesiveness and environmental stewardship (4)(5)

The benefits of green roofs that connect the environment, public health, and economic factors are supported by the research of Corrie Clark (a former University of Michigan, Civil and

Environmental Engineer), yearly analysis done by the University of Michigan's Psychological Services, and case studies from peer institutions.

By interviewing six deans and representatives from various buildings across the university, our goal was to connect the knowledge that was gleaned from our individual research with what stakeholders from each building already knew. The biggest constraint voiced was most frequently cost related, which will be explained further in the findings section.

The first step for the University of Michigan campus has been and always should be the promotion of student and faculty education. According to President Mary Sue Coleman, "Students are the story of environmental awareness and sustainability at Michigan". Although the concept and research for green roofing has seen substantial growth over the past few years, there is undoubtedly a large pool of student and faculty alike that are oblivious to the idea that, by simply greening a roof, profound social and economic benefits can be felt on multiple systems. Currently, green roofs have been implemented and marketed at competing colleges and universities, such as Michigan State and Penn State. As the largest research institution in the country and the "leaders and the best", we must strive to successfully meet our sustainability goals (2) by 2025. By greening the roofs of both newly constructed and renovated buildings on campus, our University has the opportunity to be at the forefront of sustainable construction practices.

Project Goals/Objectives

After our initial research of green roof technology and its application in urban environments, our team decided to focus our project on investigating U-M's impression of green roofs and the existing barriers/constraints to their implementation on campus buildings. Our team's long-term objective is to incorporate green roofs into U-M's standard construction practices, thus facilitating their installation on existing and planned campus buildings. Given the scope and timeline of our project, our team narrowed our broad objective into more realistic and achievable goals for the semester. These project goals include:

1. Analyze potential space availability on campus buildings and the constraints or barriers to implementing green roofs that influence the university's decision makers.
2. Assess the degree of interest in green roofs among the different university schools/departments and students on campus.
3. Design and present educational pamphlets outlining the various benefits of green roofing buildings to AEC, department heads/deans, students, and other stakeholders.
4. Provide a green roof design and tangible cost analysis for the installing a green roof on one specific university building – the School of Nursing.
5. Create a "virtual toolbox" that encapsulates our team's major findings, progress, and information/data to be referenced in future work on the green roof project. This toolbox would be integrated into the Office of Campus Sustainability's website.

Methodology

Research & Case Studies

During the early stages of our project, our team individually and collectively conducted research to obtain important information regarding green roof technology, its benefits, and challenges. This research was necessary to equip our team with the relevant knowledge and data that would support our project. We investigated different types of green roofs and environmental, structural, and social factors that play a role in their implementation on existing buildings and renovation or new building projects. The team also analyzed several case studies of various large-scale green roof projects around the world as well as at other top universities. We determined this information was crucial to our project's goal of proposing the implementation of green roofs to the university deans and building managers.

A3C Field Trip

On October 10th, our team, Anya Dale, and Michele Oliver went to the architecture firm, A3C, in downtown Ann Arbor to tour a green roof installed on top of their building. The trip was intended to provide first hand exposure to an existing green roof as well as to learn more about the technology from a construction firm with experience monitoring the various benefits green roofs offer. The information acquired during this trip, along with previous research into green roofs helped us determine what types of data to include in the educational pamphlets we would be distributing during stakeholder meetings (See Appendix: Figure C).

Meetings with Deans and University Decision Makers

Our team sent out formal emails to twenty various deans and facility managers around campus who we determined would be beneficial to meet with to discuss our green roof proposal. These emails introduced our project's main goals and expressed our interest in sharing knowledge of green roofs as well as hearing their thoughts and concerns regarding green roof implementation on campus buildings. The team met with eight interested decision makers at the end of October and early November. At these meetings, we distributed our educational pamphlets and introduced the various economic, social, and environmental benefits green roofs have to offer (See Appendix: Figures D & E). Depending on the meeting, we discussed what barriers or constraints were most influential in their decision not to implement green roofs, and why those obstacles outweighed the benefits described. With stakeholders already familiar and invested in green roofs, we discussed which technological factors and techniques were the most attractive to promote green roofs for future construction projects.

Designing an Online Green Roof Brochure and Toolbox for OCS

We compiled the economic analysis data that Dr. Corrie Clark provided us, the information acquired from A3C, our individual research findings, and feedback from our various stakeholder interviews to design a green roof informational pamphlet, which would be made

available to stakeholders online. This brochure will include visual aspects of green roofs, initial costs of installation, and what cost savings could be anticipated over the lifetime of the roof. Using similar data and additional research, we also intend to establish an online toolbox on the Office of Campus Sustainability website that would assist future student groups and on-campus advocates to continue the work that we started this semester. Our goal with this toolbox is to ensure the progress made with the stakeholders can be built upon to further this opportunity in future semesters.

Final Proposal for Implementing Green Roofing on the School of Nursing

Our meeting with the School of Nursing was particularly successful and after they demonstrated strong interest in installing a green roof in the design of their new building, we continued to work with them to develop a proposal for such a green roof. The proposal includes an architectural design of a green roof on their new building as well as a quantitative cost analysis of implementing and maintaining such a roof (See Appendix: Figure E). In addition, it reiterates the long-term economic, social, and environmental benefits of installing a green roof on their new building.

Findings

One of the most informative interviews that our team conducted was on November 11, 2012 with Corrie Clark, a former University of Michigan student who finished her PhD in 2008 in civil and environmental engineering. Our team spoke with her about her master's project on green roofing as a method of stormwater management, which she was inspired to do as a result of taking Jonathan Bulkly's class on 'Water Policies'. She determined the best method for stormwater management on impervious surfaces at the University of Michigan was green roofing. Dr. Clark began her analysis by considering all roofs on campus and by assessing the structural feasibility of installation. She narrowed down the buildings that would most benefit from green roofs to two: the Mott Hospital and the Art & Architecture Building on north campus.

Through her research, Dr. Clark discovered that the average roof replacement for buildings at the University of Michigan is 15 years, compared to a conservative lifetime for green roofs of at least 40 years. She obtained this information from research done on green roofs in Portland, Oregon and Germany, which have many green roofs over 40 years old. When she did further research on the Art & Architecture school, Dr. Clark found the main difficulty they had with stormwater was because of major flooding whenever it rained. Dr. Clark's research indicated that a green roof would be feasible on this building, although outside engineers hired by the university determined the opposite. Therefore, the university decided not to put a green roof on this building. She also ascertained that the maintenance for the green roofs would be quite reasonable since it is covered for the first 5 years after installation. Afterwards, the roof becomes essentially self-sustainable, and only a few functional aspects need be checked. Actual data on cost savings concluded that a 20,000 sq. ft. green roof at the University of Michigan,

compared to a conventional roof, would save $200,000 solely from increased longevity, health savings, and storm water tax credits gained. (See Appendix: Figure B).

Another very instructive aspect of our project was reaching out to the deans of many of the different schools within U-M and meeting with them to propose the idea of green roofing. The first meeting we went to was for the School of Nursing. We met with Carleen Champagne the project-planning manager for the nursing school's new building. During this meeting, Carleen indicated that the dean and others stakeholders for this project were very interested and were already considering including a green roof in their construction plans. Since health and wellbeing are some of the main focuses of this school, they thought the idea of a green roof would go hand in hand with these goals. However, their construction budget was the main constraint, restricting them to only install a green roof on the smaller of their two possible roof options. We proposed to Ms. Champagne the prospect of installing a green roof on the smaller roof initially but to make the larger roof structurally sound enough for potential green roof implementation during reconstruction. With the economic paybacks they will receive from the smaller roof, they will be able to invest in a green roof for the larger roof in the future. Without the cost constraints, they initially envisioned green roofs on both the smaller roof and larger one. Ms. Champagne's main concern was regarding maintenance requirements and costs of green roofs, which encouraged our group to conduct further research into this topic and how schools, such as the Ross Business School, manage their green roof's maintenance. By the end of the meeting, Ms. Champagne informed us that she was 90% sure that they would put a green roof on their new building which would be about a $90,000 project.

The second meeting we went to was for the School of Public Health with Al Franzblau, the dean of the School of Public Health, and Jim Kennedy, the facilities manager. It was immediately brought out that, although they are interested in sustainability and support the university's commitment to sustainability, green roofing was not feasible for them. Of their two buildings, one cannot structurally support a green roof and the other is considered a "hot" roof, meaning no one is permitted on the roof without protective Hazmat gear because of the dangerous and harmful fumes emitting from the labs below. Renovation is unlikely in the near future.

The third meeting was with the School of Public Policy. We met with Bill Kelly, the facilities manager, who invited us to propose our ideas to the Fords School's 'Green Committee.' They expressed interest and enthusiasm in green roofing above their underground lecture halls and classrooms. Mr. Kelly expressed that they envisioned this green roof on the ground level like at north quad. He explained that they have not currently pursued green roofing since they are unsure if they can afford to install one or if their building meets the specifications for one. Their primary lure to greening this space was due to the building's unused, barren, and unattractive aesthetics.

The fourth meeting was for the Ross School of Business with Allan Cotrone, the chief administrative officer and Chuck Amyx, the director of operations. Since, they currently have three green roofs on the Ross building, the purpose of this meeting was to learn about the process

of installing the green roof, the LEED certification awarded for the building, and the maintenance requirements. Cotrone explained that the green roof space is approximately 20,000 square feet, but it is not all connected, which meant it did not contribute towards the building's LEED silver certification. An outside maintenance company was hired for the first four to five years to irrigate and weed the roofs until they became well established. This maintenance company was directly paired with the green roof construction company so they were specialized in green roof maintenance. Then, the frequency of maintenance significantly decreased, as the need for irrigation and weeding dwindled. The green roof has been used for tours for both the University of Michigan and for outside universities. Mr. Cotrone and Mr. Amyx were convinced to implement green roofing because it is environmentally and financially responsible, "it just makes sense," they said.

A fifth meeting was held with representatives from the School of Music: Mary-Alice, the facilities operator, Dean Kendall, and Evan Chambers, Chair of Composition. All three stakeholders informed us of their upcoming construction and interest in greening their roof. However, the School of Music has an extremely tight budget and further economic support would be needed through additional sponsors. Additionally, Evan Chambers informed us that multiple board members and one prominent sponsor has advocated for greening the Moore Building. In summation, the newly constructed building may contain a 20,000 sq. ft roof capable of providing the school with numerous quantifiable benefits. At this point however, obtaining funding in the future for a green roof is not realistic. While interest was expressed, the lack of feasibility was a huge barrier.

The final meeting took place at The Graham Institute of Sustainability. Andrew Horning, the Acting Director, expressed interest in the idea of green roofing at the University of Michigan. Mr. Horning suggested that we communicate with the Student Sustainability Initiative to ensure that we foster a network of communication between the university decision makers and student initiatives.

Recommendations

While the implementation of green roofs on campus will require continued advocacy and outreach over the years, our findings have created the foundation for the University of Michigan campus to continue to explore them in future projects. As the University of Michigan transitions towards the future, in order to increase the implementation of green roofs, one crucial structural resource must be placed on an online database and, using both top-down and bottom up methods, an approach with the inclusion of all stakeholders must be used. After meetings with various stakeholders and several deans of the university this past semester, we have concluded that the most significant barrier to green roof implementation is the lack of a single central database as well as tight budgetary constraints. In response, our green roofing team proposes two structural changes and one future goal in order to sustain and promote the future of green roof implementation on the U-M campus.

Firstly, we propose to add a structural amenity using a bottom up approach, by creating a student advisory board. The board will consist of dedicated students who continue to meet with deans and other stakeholders, particularly those planning construction. The board members will be provided our projects research, access to the Green Roof Toolbox, and a list of beneficial contacts going forward. Additionally, we will provide the advisory board with recommendations on how to market the green roof product, how to obtain a roof's weight capacity, square footage, and direct them towards local companies that can provide monetary quotes. The board will collaborate with various stakeholders and reinforce the options and benefits of a green roof. Additionally, they will be responsible for acting as a location for said stakeholders to find out the construction and maintenance costs of greening their roof in comparison to a conventional roof.

Our second goal is to provide the option for architects on campus to "select" for the addition of green roofs in future renovations and constructions they pursue. This would consist of a pamphlet that will concisely describe the cost/benefit analysis of green roofs, the structural requirements, various types of green roofs, and an estimated monetary quote for a green roof compared to a conventional roof. A case study of the design options for the U-M School of Nursing, will act as a symbolic representation for alternative U-M stakeholders debating whether or not implementation is practical and worth the initial investment. The pamphlet represents a more top-down approach, where schools planning future construction will be directed to a central database, that reinforces the benefits and options surrounding this rapidly growing green roof market. The AEC acts as a critical agent of change, capable of providing the location of where to put these U-M informational pamphlets. This information will establish collaboration amongst various stakeholders and facilitate a competition between schools within U-M, and, in the future, rival 'Big 10' schools. If the AEC is able to provide this structural resource, there is great potential to facilitate a positive feedback relationship through the competitive nature of American universities. The database will ultimately have the effect of increasing the persuasiveness of a future proposal to the provost and representing a key leverage point, where merely one "small shift" in the system, will likely cause big changes, thus helping the University of Michigan to meet its 2025 sustainability goals.

Ultimately, provided the green roofing initiative is sustained into the future, a final proposal to the provost is representative of a crucial change agent, providing subsidization and enabling many schools with budgetary constraints to construct a green roof. The proposal would be indicative of a meta-analysis. It will encompass all the findings from this past semester, any additional green roof research, and specific examples on campus, such as the School of Nursing. It will be crucial to provide the economic return on investment and the payback period, to facilitate the persuasive nature of the proposal. Furthermore, in order to increase the probability that the provost will accept the proposal, the educational benefits must be stressed. Provided an intensive and accessible green roof is established, persuasive data will be able to reference the aesthetic health benefits and foster a more informative atmosphere, using signage that explains the multitude of benefits that come from green roofing. If the provost provides funding, many deans and stakeholders would then be able to construct the green roofs they hope for. The

increased implementation of green roofing will lay the foundation of a positive feedback loop in regards to other universities. Such positive feedback will allow green roofs to become the norm so that every school will have the incentive to build green roofs, helping to restore nature's balance whilst improving their own university's public image.

Ultimately, our group hopes to provide a complete, community based structure that not only sustains the green roofing initiative, but also fosters the collaboration amongst deans, stakeholder, students and faculty. Although our group understands that policy change at such a large institution takes time, we are confident that the necessary change agents have been set, to continue pressuring decision makers at the U-M in hopes to persuade the provost for subsidization of future green roof construction.

Conclusion

Upon meeting with many Deans and Stakeholders, we quickly learned that the biggest barrier was initial cost of implementation, and for this reason we reworked our proposal to emphasize a good financial model as opposed to the environmental benefits. We obtained information from existing green roofs such as at the Ross School of Business and passed our knowledge on to interested implementation projects like that taking place at the School of Nursing.

As the semester comes to an end, we want to ensure that our work continues to make an impact on campus for the promotion and implementation of green roofing. To do this, we have produced a pamphlet for AEC to make available to decision makers and stakeholders. Planners will find information on how to green their buildings, including the benefits of green roofing as a sustainable practice. Furthermore, we have initiated a student advisory board in order to emphasize student interest in sustainability at the University of Michigan. With these two outcomes, we have prompted collaboration between top-down decision makers and bottom-up student interests to stimulate a network of a school wide interest in green roofing that will accelerate in years to come.

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Appendixes:

Figure A:

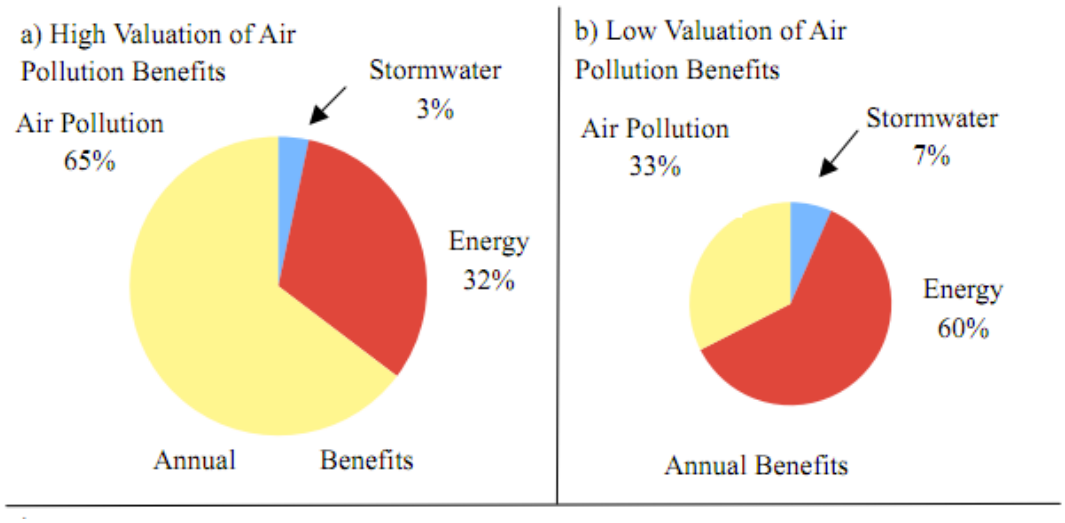


Figure taken from source: Clark, C.E. (2008) "Energy Emissions Mitigation using Green Roofs: Probabilistic Analysis and Integration in Market-Based Clean Air Policies"

Figure B:

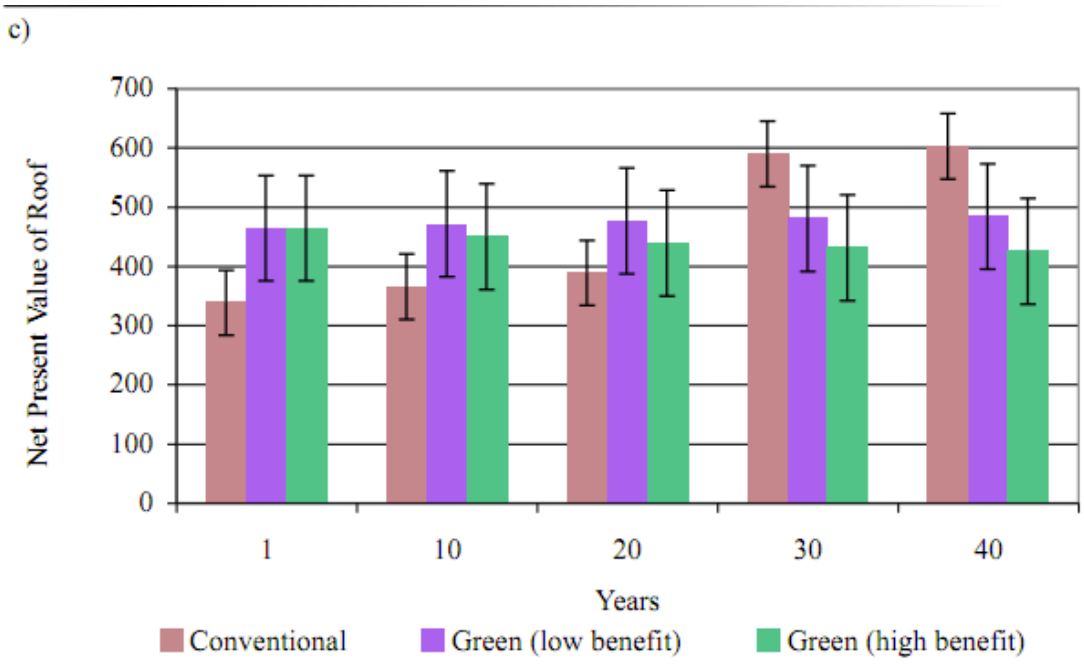


Figure taken from source: Clark, C.E. (2008) "Energy Emissions Mitigation using Green Roofs: Probabilistic Analysis and Integration in Market-Based Clean Air Policies"

Figure C:

Figure D:

Green Roof Initiatives on U-M's Ann Arbor Campus
Meeting with Allan Cotrone-Chief Administrator Officer, and Chuck Amyx- Director of Operations
Ross School of Business- Friday, November 9th at 2pm in R2430 Hickman Conference Room
Interview Outline:

1. Introduction
    a. Names, Majors and Interest in Green Roofing
    b. Env.391-Sustainability and the Campus- Explain project
    c. Promoting Sustainability at U-M by increasing awareness of benefits and feasibility of Green Roofing
        i. U-M's 2025 Sustainability Goals:
            - *Healthy Environments*: 20% Sustainable food purchases; protect Huron River quality by minimizing runoff from impervious surfaces
            - *Climate Action*: reduce GHG emissions by 25%
            - *Community Awareness*: pursue stakeholder engagement, education and evaluation strategies towards campus-wide ethic of sustainability
2. Known Benefits of this Sustainable Systems/Case Studies
    a. The range of benefits of greening a roof
        j. Economic
            - Longevity - roof life increases 2 to 3 times
            - Heating/Cooling savings up to 30%
            - Decrease in rainwater runoff tax (receive credits)

        ii. **Environmental**
            - Reduces urban runoff into Huron River
            - Promotes Local food systems
            - Sequesters CO2; improves air quality
            - Absorbs solar radiation, decreasing Greenhouse effect

        iii. **Community and Health**
            - Proven to increase community cohesiveness and mental health through physical activity and social space
            - Views of green roofs increase workers productivity
            - Environmental Stewardship – class interactions would promote campus enhanced sustainable initiatives

        iv. **Corrie Clark- 2008 U-M PhD Civil & Env. Engineering**
            - Comparative study of 12,000 sq.ft. Conventional and Green Roof
            - Initial Costs: Green Roof- $464,000; Conventional- $335,000
            - Predicted long term savings over 40 years = $200,000
            - Long-term payoff will absorb the initial investment of greening a roof (about 30% annual savings)
3. Ross School of Business: 3 Green Roofs
    a. LEED Silver certified, 9,050 sq.ft. of Green Roof
    b. Xeroflor company - Architect, Installer and Landscape Architect
    c. Extra costs to hire special maintenance for roof?
    d. Are there records for cost savings, or health benefits
    e. Accessible for workshops or student classes?
4. Campus wide recommendations/ how to engage others
    a. AEC website/pamphlet for Green Roofs
    b. Influencing new constructions is easier than renovating old
        - Progress: Mott's Childrens Hospital, N.Quad, Ross School and very possibly new Nursing School
    c. Enhance U-M's competitive edge for Sustainable Practices amongst leading Universities:
        - UVA, UNC, UPenn, U-Wisconsin, U-Vermont
        - U-Texas School of Public Health has implemented green roofs

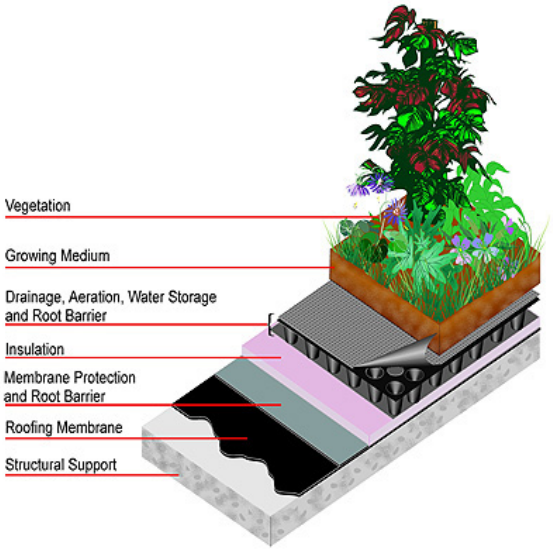
Figure E:

Proposal to School of Nursing for Installation of Green Roof

What are Green Roofs?

A green roof, or rooftop garden, is a vegetative layer grown on a rooftop. Green roofs have a layer of living plant on top of the structure and the waterproofing elements.

Green roofs can be installed on a wide range of buildings, from industrial facilities to private residences. They can be as simple as a 2-inch covering of hardy groundcover or as complex as a fully accessible park complete with trees and gardens.



(Low Impact Development Center. http://www.lid-stormwater.net/images/greenroof1.jpg)

What are the Benefits?

- Reduce roof stormwater: in some cases this can help reduce the size of stormwater pipes, and the amount of stormwater that needs to be treated by municipal water treatment. In addition, green roofs filter pollutants from rainfall. *A North Carolina study looked at the performance of a green roof and found that it reduced runoff during peak rainfall events by more than 75 percent.*

- Increased roof longevity: Protects the roof membrane from harmful ultraviolet radiation and acid rain, which slowly corrodes the roofing material. Only a couple inches of soil can greatly extend the life of the roof, reducing the necessity to constantly replace the less sustainable conventional roof. *A green roof lasts on average 2-3 times that of its conventional counterpart and is estimated to sustain itself for up to 40 years.*

- Reduced energy use: Green roofs absorb heat by acting as natural insulators for buildings, reducing the consumption of energy for heating and cooling. *A 32,000- square foot green roof implemented in Canada saved 6 percent on total cooling and 10 percent on total heating costs each year.*

- Green roofs remove particulate matter (PM) and other gaseous pollutants from the air, providing cleaner air, a source of oxygen, and a habitat for birds and insects. *A study in Washington, D.C assumed 20 % of all roofs greater than 10,000 square feet were greened. The results showed that 6.0 tons of O3*

(ozone) and 6 tons of PM would be removed per year, equivalent to the quantity absorbed by 25,000 to 33,000 trees.

- The aesthetic value of green roofs provides health benefits. When physically seeing or interacting with an aesthetically pleasing space, people are relieved of stress and can enter a more joyful and relaxed mental state. *A study in Texas, involving post surgery patients showed that recovery was faster and had less chance of relapse if patients could look out onto green space*.

Types and Options of Green Roofs:

	Extensive Green Roof	**Semi-Intensive Green Roof**	**Intensive Green Roof**
Maintenance level	Low	Periodical	High
Irrigation requirement	No	Periodical	Regularly
Plant communities	Mosses, Sedum, Herbs and Grasses	Grass, Herbs and Shrubs	Lawns, Perennials, Shrubs and Trees
Build-up height	60 - 200 mm	120 - 250 mm	150 - 400 mm on underground garages > 1000 mm
Added Weight Load	60 - 150 kg/m2 13 -30 psf.*	120 - 200 kg/m2 25 - 40 psf.	180 - 500 kg/m2 35 - 100 psf.
Use	Ecological protection layer	Designed Green Roof	Park and/or Garden

*pounds per square foot

School of Nursing Cost Summary						
	Interaction Roof		Upper Roof West		Combined Roof	
Rooftop Area (m2)	223		604		827	
Roof Type	Conventional	Green	Conventional	Green	Conventional	Green
Roof Lifetime (years)	20	40	20	40	20	40
Installation Cost per m2	$167.00	$232.00	$167.00	$232.00	$167.00	$232.00
Initial Investment Cost	$37,241	$51,736	$100,868	$140,128	$138,109	$191,864
HVAC Cost per m2	$1.62	$0.78	$1.62	$0.78	$1.62	$0.78
Stormwater fee per m2	$0.08	$0.02	$0.08	$0.02	$0.08	$0.02
Health Benefits per m2	$-	$1.08	$-	$1.08	$-	$1.08
Annual Health Benefits	$-	$240.84	$-	$652.32	$-	$893.16
Annual Cost (no health)	$379.55	$179.29	$1,028.01	$485.62	$1,407.55	$664.91
Annual Savings	$-	$200.25	$-	$542.39	$-	$742.65
Annual Savings w/ Health	$-	$441.09	$-	$1,194.71	$-	$1,635.81

*Installation Costs based off current competitive costs of installing conventional vs. green roof (10" depth)
*Heating, Ventilation, and Air Conditioning costs based off study by Dr. Corrie Clark on U of M buildings
*Stormwater fee based off current taxes levied by the City of Ann Arbor
*Health Benefits based off EPA estimates of NOx emission reductions' effect on public health

Lifetime Cost Analysis Without Health Benefits						
School of Nursing Roof	Interaction Roof		Upper Roof West		Combined Roof	
Roof Type	Conventional	Green	Conventional	Green	Conventional	Green
Roof Cost after 5 years	$39,138.73	$52,632.46	$106,008.04	$142,556.08	$145,146.77	$195,188.54
Roof Cost after 10 years	$41,036.46	$53,528.92	$111,148.08	$144,984.16	$152,184.54	$198,513.08
Roof Cost after 15 years	$42,934.19	$54,425.38	$116,288.12	$147,412.24	$159,222.31	$201,837.62
Roof Cost after 20 years	$82,072.92	$55,321.84	$222,296.16	$149,840.32	$304,369.08	$205,162.16
Roof Cost after 25 years	$83,970.65	$56,218.30	$227,436.20	$152,268.40	$173,297.85	$208,486.70
Roof Cost after 30 years	$85,868.38	$57,114.76	$232,576.24	$154,696.48	$318,444.62	$211,811.24
Roof Cost after 35 years	$87,766.11	$58,011.22	$237,716.28	$157,124.56	$325,482.39	$215,135.78
Roof Cost after 40 years	$89,663.84	$58,907.68	$242,856.32	$159,552.64	$332,520.16	$218,460.32

*Lifetime analysis assumes the conventional roof will be replaced after 20 years