To: Professor Benjamin Cohen
From: Alex Huntowski, Aleks Kopera, Emanuel Gurara
Subject: Project Memo – Green roof on New Williams Art Center
Date: May 9th, 2013

Introduction:

Buildings currently use approximately 50% of our energy in the U.S. The 20th century construction boom increased CO_2 levels which increased global temperatures as well. While the issue has not yet reached a critical level, it soon will. Consequently, the construction and building industries are actively looking for ways to improve energy efficiency in buildings. One of the most promising technological improvements are Green roofs.

Our project seeks to educate students on the benefits and implementation of Green roofs. Our first question was to determine what is the best Green roof design for the new Williams Arts Center? Our next step was to develop a way to communicate Green roof design decisions to the general public. We did this by centralizing our research, methods, and results on a website so it is accessible to those interested.

Significance:

Green roofs have environmental, cost-saving, personal and educational benefits:

Green roofs have a multitude of environmental benefits that standard roofs do not have. The first of which is higher energy efficiency. Due to the layers of soil and rainwater retention properties, Green roofs actively cool the surface which they cover. Furthermore, many buildings in cities like Easton use dark roofing that absorbs sunlight. This absorbed sunlight is transformed into heat, and actively warms the city. This effect is commonly known as the heat island effect. Green roofs, due to being naturally vegetated and cooling, help negate the heat island effect and contribute to a more comfortable climate. Additionally, the Green roof's vegetation actively absorbs carbon dioxide through the process of photosynthesis. This process contributes oxygen and resultantly a cleaner city. The vegetation and soil also help to reduce stormwater run-off. The plants use the water to grow, and the additional water is purified through the soil.

Vegetated roofs also provide long term cost saving benefits for the building's owner. One example of how Green roofs do this is by extending the roof's life by two to three times that of a traditional roof. Traditional roofs have an average lifespan of fifteen to twenty years and some Green roofs in Germany have lasted up to 90 years. The reason Green roof's last so long is because its vegetation layer protects the waterproofing membranes from temperature fluctuations and ultraviolet radiation which create micro tears. Green roofs also decrease the owner's need for noise insulation because Green roofs absorb a wide variety of sound frequencies. Additionally, The building owner saves money on his/her heating and cooling bill because the Green roof's natural thermal insulation properties prevents heat from escaping through building's roofs. The building would also require less infrastructure to manage stormwater run-off because the

vegetation on roofs uses stormwater to survive. The city of Portland's Department of Environmental services did a study in 2007 that showed that Green roof's have a water retention rate ranging from 22% to 66% depending on the amount of rainfall and the Green roof's substrate depth.

Green roofs also have mental benefits for those who live by and see them on a daily basis. The hypothesis is that when people are surrounded by nature their productivity, health and emotional states are enhanced. People's thoughts usually center on natural surroundings meaning their awareness isn't on themselves or their problems. This momentary escape is thought to reduce stress and increase a person's comfort level. According to greenroofs.com, "distinct therapeutic links exist between moods, health, re-cooperation time and nature. It has been suggested that mental health and emotional stability are positively influenced by green spaces and with interactions of other elements of nature" (Greenroofs.com). This is an enticing feature for a college campus. If students are happier and more productive, they usually perform better academically.

The University of Virginia, Cornell University and the University of Pennsylvania are all examples of universities that have implemented green technologies into their buildings--specifically Green roofs. Green roofs have proved to be functional and aesthetically pleasing while exposing students to the garden cultivation process. Green roofs have also proven to be valuable to students who are doing research on sustainability or agriculture. For example, Pennsylvania State University uses a 4,500-square-foot Green roof as "a research site for horticulture students who monitor the quality and quantity of stormwater running off the roof" (Governance).

Lafayette College has already begun to incorporate Green roofs in campus buildings. Lafayette's 2009 Campus Master Plan included a Green roof project on their Engineering building which "acted as a pilot program for the college to determine the feasibility of future Green roof initiatives" (Governance). This pilot program was a success which spurred the Skillman Library Green roof Initiative. The previous participants described why they decided to place a Green roof on Skillman Library with their acronym SLUGGER: "Skillman Library United Green Gardening Education Roof." "[They] chose to locate [their] Green roof proposed project on Skillman Library because of the central role it plays on campus; it is a commonplace for all to congregate and spread knowledge" (Governance). They also felt that its central location on campus would raise awareness on the benefits of Green roofs.

Our group decided to design a Green roof for the new William Arts Center building instead because it is easier and cheaper to install a Green roof on a new building than on an existing building.

Methods:

We looked at our project from a six step approach. We felt it was an important first step to understand the larger picture regarding why we need Green roofs before exploring Green roofs themselves. As a result, our preliminary research was on climate change and the green building movement.

We then broadened our research to Green roof construction, materials, and vegetation. We thought it was an appropriate next step to analyze the technical

information. We formulated our initial designs including potential growing medium, vegetation, insulation, waterproofing, and membrane during this phase.

As a next step, we met with our contact, Mary Wilford Hunt, a licensed architect and professor here at Lafayette College. She helped us narrow down the types of materials and vegetation we should be looking for, and the general scope of our project. Her information helped us specify our approach and move forward into the final phases of our project.

The fourth step in our approach was to develop a project proposal of the design of the Green roof. This proposal was to be used by more technical professionals, such as architects, engineers, and contractors. Within this proposal, we outlined the components of the potential Green roof, along with the specific materials that comprised the layers.

Our fifth step was to develop an informative website to communicate our findings to students and anyone else interested. While our project proposal emphasized the technical, our website emphasized information that was accessible to everyone. It was our responsibility to take in this technical information and communicate it in a way that was understandable to someone who had no prior knowledge of Green roofs.

Our final step was to outline a plan for future classes and Green roof advocates. Like the SLUGGER project before us, we wish for future students to continue on our Green roof research, and perhaps implement a Green roof on another structure around Lafayette's campus. Our project was as much a comprehensive design analysis as it was a teaching tool for students to come.

Analysis:

Our project is a culmination of several projects. One aspect of our project is the Green roof project proposal. This document explains the installation of a Green roof atop the new Williams Arts Center from a construction perspective. The proposal in formatted to reflect a professional proposal, one that may be used as reference during the construction process. Here, we give a brief background of the project, a description of the project team, and most importantly, a preliminary design of the Green roof. This design includes the structural components of the Green roof – i.e. its layer design and the materials used in these layers. In addition to the design, we calculated the maximum load the roof would produce on the building based on the materials chosen. As a final step, we analyzed past life cycle costs analyses to determine to potential costs associated with the Green roof.

The second component of our project is an informative website about Green roofs. This website includes knowledge more applicable to the lay reader, including background, historical significance, contexts, benefits, and a copy of our project proposal. We thought this was the most important aspect of our project, for while construction managers and architects understand Green roofs and their applications, students and other readers may not. We wanted to provide an accessible knowledge base for Green roof information in hope that it would educate students on the importance of sustainable technologies and their associated practices. Furthermore, we hope that our website will serve as a study tool for future engineering studies majors. The nature of the major is inherently broad, and we believe our website will help communicate to students one of the many topics engineering studies majors are interested in.

Conclusion & Recommendations:

After studying the benefits of Green roofs, we recommend one be installed a top the new Williams Art Center building. While not as many construction firms are as familiar with Green roofs as they are asphalt roofs, we believe that a vegetative roof is the overall best choice for the new campus building.

The roof serves as a testament to Lafayette's dedication to sustainability and environmental preservation. We hope that, if the roof is eventually constructed, it will serve as a model for future Green roofs on campus.

As a team, we believe the project was a valuable experience. We were able to use our studies of contexts and influences on a modern example. While many other issues we studied in class were past cases (and consequently solutions and forethoughts are in retrospect), this example was a working solution towards a current problem. Through projects such as these, we are able to examine contexts and their associated solutions in real time. In conclusion, looking at contexts in real time helps one negate the potential problems of the future, and perhaps prevent them from occurring entirely.

*For technical recommendations, see Appendix B

Signatures:

Alex Huntowski

Aleks Kopera

Emanuel Gurara

Appendices:

Appendix A: Annotated Bibliography [pgs.4 - 14]
Appendix B: Technical Recommendations [pgs. 14 - 17]

Appendix A:

Peer Reviewed Sources:

Almusaed, A. (2011). *Biophilic and bioclimatic architecture.* London, England: London-Springer. DOI: 10.1007/978-1-84996-534-7

This book explains the fundamentals of biophilia, the study of the nature's effect on the human psyche. This text does not argue anything, rather, explains the context of biophilia, its uses in architecture, and gives a detailed explanation of the various types of plants/vegetation that are associated with biophilia. The author, Amjad Almusaed, is an architect with a PhD in environmental design. This source will be valuable for explaining biophilia from a more academic perspective. The book will also provide

valuable background information on the biophilia that can be used to explain the effects a Green roof will have on the surrounding environment.

Ascione, F., Bianco, N., de' Rossi, F., Turni, N., & Vanoli, G. P. (2013, April). Green roofs in European climates. Are effective solutions for the energy savings in air-conditioning? *Applied Energy,* 104, 845-859. doi: 10.1016/j.apenergy.2012.11.068

This article investigates the economic feasibility of the potential benefits gained by implementing roof vegetation. The authors attempt to verify the usefulness of Green roofs while focusing strictly on environmental and energy aspects that influence their performances. The study was conducted using a range of variables including climates, rainfall intensity, type of irrigation, and building use. The authors were able to evaluate the technical and economical feasibility of Green roofs applied to a modern office building, considering various vegetation and different external coatings, concluding that cool roofs, by means of high-reflective and high-emissive coatings, strongly improve the summer performances, with low extra costs for installation and maintenance. This article is useful because it provides a wide analysis of the technical–economical feasibility of Green roofs.

Beatley, T. (2011). The importance of Nature in our Urban lives. Biophilic Cities: Integrating Nature into Urban Design and Planning, 1-17. Washington, DC: Island Press.

Beatley explores the positive aesthetic effects of Green roof systems on our human psyche, making the case that nature is vital to human existence. The author pleads that the limited knowledge our youth has about the natural world paints a pessimistic picture about the future of our environment and community. The article implies that society needs to focus on education and the prolonging of our environment and community. We found this research to be beneficial to our project in accordance with the cultural, value-latent aspects of Green roofs, providing a non-technical context for Green roof technology.

Calkins, M. (2009). *Materials for Sustainable Sites: A complete guide to the evaluation,selection, and use of sustainable construction materials.* Hoboken, NJ: John Wiley & Sons.

This source is a guide to choosing the most environmentally friendly and cost effective materials. The book details the benefits of each material, the advantages and potential downsides associated with their use, the construction and deconstruction process of these materials, and many other helpful pieces of information as well. The author, Meg Calkins, a LEED AP, is familiar with green materials. Her jobsite experience and colleague interactions helped her obtain valuable information regarding green materials. She explains the process for successfully choosing and acquiring materials, the benefits and consequences of the location choices. It is important to

understand existing sustainable resources so the Green roof suits the environment it is built in.

This source will be a great resource for later phases of the project (feasibility/design). It will be important to choose the best resources and materials given Easton, PA's environment.

Cantor, S. L. (2008). *Green roofs in sustainable landscape design.* New York, NY: W.W. Norton & Co.

This book offers information on the sustainable design of Green roofs aimed to design professionals, practitioners, and students. Author Steven Cantor discusses the design process in detail, dividing everything from the initial decision to maintenance into an eleven step cycle. Furthermore, the author profiles the major Green roof plant suppliers in North America as well as discussing the specifications needed for Green roofs. The book concludes with case studies of Green roofs in Europe and North America where the author gives the reader a sense of typical design approaches and insights into implementing such technologies in the past. This book is useful because the examples in the case studies are diverse, and the degree of detail is not limited even though the author covers a wide range of material.

Chang, N., Rivera, B.J., & Wanielista, M.P. (2011, July). Optimal design for water conservation and energy savings using Green roofs in a green building under mixed uncertainties. *Journal of Cleaner Production,* 19(11), 1180-1188. doi: 0.1016/j.jclepro.2011.02.008

This article focuses on Green roofs with respect to the trades-offs between cost-effectiveness, cost-benefit, and cost-risk using a multi-criteria decision making process. In acknowledging the high initial capital investment of water conservation and energy saving endeavors, the authors seek to test if the added benefits of the green initiatives actually outweigh the initial cost. The optimal area of Green roof to balance cost, benefit, and risk assessment was unknown until a programming model was built to address the optimal design strategies under mixed uncertainties. This article will serve as a technical resource identifying the optimal Green roof area that keeps within the cost of a conventional structure over a span of 50 years.

Dunnett, N., Gedge, D., Little, J., & Snodgrass, E. (2011). *Small Green roofs: Low tech options for greener living*. Portland, OR: Timber Press.

The authors of *Small Green roofs: Low-tech options for greener living* are reputable in the field of Green roofs. Nigel Dunnet is a professor of Planting Design and Vegetation Technology and the Director of the Green roof Center at the University of Sheffield; Dusty Gedge is the President of the European Federation of Green roof Association; Edmund Snodgrass started the first Green roof nursery in the United States located in Maryland; and John Little is a partner in the Grass Roof Company, a landscape contracting company located in the United Kingdom. After individually participating in the development of small scale, domestic, self-made Green roofs, these four Green roof specialists came together under the shared belief that small scale, self-made Green roofs are more sustainable than large, commercial Green roofs. They believe that the personal,

individualistic nature of self-made Green roofs coincides with a higher degree of ownership and care from the Green roof developer. Using forty small, domestic, commercially or self-built Green roof profiles from around the world, the authors of this book hope to encourage people with little knowledge on Green roofs to initiate, install, construct, and plant their own, personal Green roofs.

Although the new William Arts Center Building would be considered a large scale project, this book would give our team a better idea of the Green roof design process. This information would make us better prepared to involve ourselves in the project as opposed to depending on an outside party to make every design, construction and installation decision.

Getter, K., & Rowe, B. (2006). The role of extensive Green roofs in sustainable development. ***Horticultural Science & Biotechnology*****,** ***41*****(5), 1276-1285. Retrieved March 18, 2013, from http://hortsci.ashspublications.org/content/4**

Kristin Getter has a PhD in Horticulture from Michigan State University and currently works there as a Floriculture outreach specialist. Bradley Rowe has a PhD in Horticulture from North Carolina State University and is currently a professor at Michigan State University. These two horticulture specialists co-authored this journal article to inform its readers of the current knowledge available on Green roof technology. This includes Green roof benefits, factors that affect Green roof plant selection, plant installation and maintenance, as well as barriers to Green roofs in the United States.

This article will serve as valuable background information for this project. We understand that we would have to double-check on any information we decide to use for the design of our Green roof because of the article's publication date.

Grondzik, W.T. & Kwok, A.G. (2011). ***The green studio handbook: Environmental strategies for schematic design (2nd ed).*** **Burlington, MA: Elesevier.**

This book explains the fundamentals of green design from an architectural perspective. Both authors are professional architects with years of experience in both green and traditional design. Using drawings and pictures, the authors explain when to use a variety of sustainable designs and technologies, including day lighting, passive heating, and increased ventilation. While some of these concepts do not directly apply to Green roofs, they will be important in understanding how Green roofs function with the rest of the building.

Given that we will be working with an Architect on our project, it will be important to know the fundamentals of the sustainable design process. It will make communication within our team easier and expedite the design process. Furthermore, understanding schematic design will help us create the best possible design given the nature of the project.

Joye, Y. (2007). Architectural lessons from environmental psychology: The case of biophilic architecture. ***Review Of General Psychology, 11 4,*** **305-328.**

This article argues for the positive effects nature has on our psyche. In essence, biophilia is the idea that nature has a positive impact on humans. It promotes a positive mood and an increased sense of productivity. The author, Yannick Joye, a business economics and strategic policy expert at the free University of Brussels, analyzes biophilia from a psychological perspective. Joye argues that nature has a positive effect on humans that cannot be replicated elsewhere. As a result, using nature in design will be beneficial to both the worker and the employer (in the sense of business). This source will be valuable for arguing/defining the positive effects of visible nature in structures, and ultimately promoting the construction of a Green roof.

Lundholm, J., MacIvor, S., MacDougall, Z., & Ranalli, M. (2010). Plant species and functional group combinations affect Green roof ecosystem functions. PLOS ONE 5(3): e9677. DOI:10.1371/journal.pone.0009677

Jeremy Lundholm, PhD, a biology professor at Saint Mary's University, Scott McIvor, a PhD candidate at York University whose research consists of how biodiversity affects ecosystems in constructed habitats, and St. Mary University graduate students Zachery MacDougall and Melissa Ranalli worked together to study how different plant species combinations and their make-up affect Green roof ecosystem functions. The Green roof ecosystem functions that they studied were water retention and summer roof cooling. These biologists compared extensive modular units consisting of one, three, or five different types of native life forms on a 5 meter high roof located in Saint Mary's University campus in Halifax, Nova Scotia and measured which combination enhanced the above stated Green roof ecosystem functions the most. Their study concluded that a Green roof mixture of tall forbs, grasses, and succulents created the best results and that further study needs to be done on biodiversity and its effects on Green roof ecosystem functions.

The plants and climate in this study are native to Nova Scotia preventing us from using its results directly; however, my team now knows that we need to look at biodiversity in Green roofs and this study gives us a framework for determining the proper plant species combination.

Pearce, A.R., Ahn, Y.H., & HanmiGlobal (2012). *Sustainable buildings and infrastructure: Paths to the future*. New York, NY: Routledge.

The authors, Annie Pearce, Yong Han Ahn, are both associate professors in the field of building construction/construction management and have a background in sustainable design. The final author, HanmiGlobal, is a global project management and construction company that is a member of the USGBC. The book explores the historical context of sustainability in the built environment, the various green rating systems, and the best practice principles in regard to design and construction. Most importantly however, the authors make a business case for sustainable design through evidence of annual energy and water savings, along with unrealized benefits. This source will help

solidify the argument for green building and its benefits, and provide a historical context for the development of green structures such as Green roofs.

Saiz, S., Kennedy, C., Bass, B., & Pressnail, K. (2006). Comparitive life cycle assessment of standard and Green roofs. *Environmental science and technology*, *40*(13), 4312-4316. Retrieved March 19, 2013, from http://pubs.acs.org/doi/full/10.1021/es0517

University of Toronto civil engineering professors, Susana Saiz, Christopher Kennedy, and Kim Pressnail created this comparative life cycle assessment of standard and Green roofs with University of Toronto's Environment Canada group member Brad Bass. This study compares life cycle environmental impacts of an eight story building in Madrid over 50 years when equipped with a Green roof, a reflective white roof, and a standard gray gravel flat roof. The life cycle assessment takes into account all benefits of Green roofs but primarily focuses on their potential energy saving performance. The study concluded that the low solar absorbance property of Green roofs and reflective white roofs can create a 1% to 5.3% reduction in environmental impacts. The authors also concluded that environmental impacts can be further reduced if Green roofs are widely used in an urban area because it would reduce the urban heat island effect.

My team can't directly use this study as an argument for implementing a Green roof at Lafayette College because it analyzes the environmental impact of an eight story building in Madrid; however, we can use it as a framework for our own comparative life cycle assessment of standard and Green roofs on one to two story buildings in Easton, Pennsylvania.

Sheng, L. X., Mari, T.M., Ariffin, A. R., & Hussein, H. (2012, July). Integrated sustainable roof design. *Procedia Engineering,* 21, 846-852. doi: 10.1016/j.proen.2011.11.2086

This article explores the possibility of combining Green roof, rain water harvest systems, and building integrated photovoltaic thermal power generation to form an integrated sustainable roof design (ISRD). The authors argue that if all these technologies were not viewed as separate, but as a single integrated design approach, decision makers would not have to sacrifice one sustainable technology for another. The study suggests that benefits to exploring ISRD include the increase of roof ambient temperature, power generation to operate irrigation systems for Green roof during draught seasons, polluted rainwater can be cleaned, and that cleaned rain water can then be used to irrigate the Green roof. This article suggests that Green roof and rain harvest systems should be combined into ISRD as the integrations will offer far more benefits.

VanWoert, N., Rowe, B., Andersen, J., Rugh, C., & Xiao, L. (2005). Watering regime and Green roof substrate design affect sedum plant growth. *Horticultural Science & Biotechnology*, *40*(3), 659-664. Retrieved March 16, 2013, from http://hortsci.ashspublications.org/content/4

This article is a part of the Master's thesis submitted by former graduate research assistant at Michigan State University's Department of Horticulture, Nicholaus

VanWoert. Bradley Rowe, Jefferey A. Andersen, and Clayton L. Rugh, whom assisted Nicholaus with his Master's thesis, are associate professors at Michigan State University in the Departments of Horticulture, Geography, and Crop and Soil Sciences, respectively. Lan Xiao who also assisted VanWoert with his research works at Michigan State University's College of Agriculture and Natural Resources Statistical Counseling Center. This 88 day study, which took place at Michigan State College, determined how water availability and different substrates influenced the growth of a sedum mixture in Green roofs. VanWoert planted seven types of Sedum in ninety-nine pots where each set of thirty-three pots contained a different substrate depth. The study concluded that "shallow substrate depths" needed to be watered every 14 days and "deep substrate depths" needed to be watered every 28 days to sustain growth. VanWoert also discovered that vegetation continued to exist after 88 days without water. VanWoert concluded that Sedum plants are suitable for the extreme conditions Green roofs are exposed to.

Since Michigan State University has a different climate than Lafayette College we cannot

directly use the results from this study; however, my team now knows that we need to consider substrate depth in terms of maintenance when designing the new William Art Center's Green roof.

Weiler, S. K. & Scholz-Barth, K. (2009). ***Green roof systems: a guide to the planning, design, and construction of landscapes over structure.*** **Hoboken, NJ: John Wiley & Sons.**

This book offers substantive and technical information on living Green roofs and goes beyond a mere overview of the Green roof movement. The extensive and international experience of both Weiler and Scholz-Barth provides for reliable advice on building ecologically practical, accessible, and useful spaces over structures. Complete with charts, diagrams, and photos, in addition to technical details, the authors have realized Green roof technology, and its wide-scale utilization as their main strategy for replenishing our diminishing recourses and integrating landscape with architecture. This book is extremely useful because as a single-source reference contains the information needed from planning and collaboration to successfully handling the technical aspects of Green roof systems, components, and applications.

Werthmann, C. (2007). ***Green roof-a case study: For the headquarters of the American society of landscape architects*** **(1st *ed*). New York, NY: Princeton Architectural Press.**

Christian Werthmann, an assistant professor of landscape architecture at the Harvard Graduate School of Design, wrote this book to explain that Green roofs should be viewed and designed as a potential new living space, not solely as way to maximize environmental benefits. His aim is to "humanize" Green roof technology using the historical context of Mediterranean roofs as an inspiration. He also argues that technological advances in Green roof technology have made them as reliable as the standard flat and sloped roofs. To make his points, Werthmann analyzes the 3,300 square-foot Green roof on the American Society of Landscape Architects' Washington D.C. headquarters from the Green roof's design to its use. This Green roof was designed

by re-known landscape architect Micheal Van Valkeenburgh. Christian Werthmann wants to prove that Green roofs that are designed to be living spaces justify their high costs by using the above case study.

Although we do not know if the new William Arts Center building will be designed with an accessible roof, this book will give my team evidence to convince the building's architects to incorporate a "humanized" Green roof.

Yudelson, J. (2008). *The green building revolution*. Washington, DC: Island Press.

This book explains the green building movement in the US and in other countries. It also characterizes the growing importance of the LEED rating system and its counterparts such as the Australian Green Stars rating system. The author, Jerry Yudelson, a LEED AP and green building enthusiast, has been involved in the green building movement since 1999. He explains energy consumption of buildings through their various processes and components, and the benefits of building green versus not. The book argues, given time, buildings that are not green will become obsolete in the real estate market and that green buildings will have an additive time value.

While this book is fairly broad, it gives an insight into green buildings as a whole. This information will be valuable in understanding why a Green roof should be implemented, and discerning if a rating system should be used for the project. Furthermore, if the scope of the project were to change, knowing more about green buildings as a whole would be helpful.

Non-Peer Reviewed Sources:

Arroyo, V. (2012, June). Vicki Arroyo: Let's prepare for our new climate [Video File].
Retrieved from http://www.ted.com/talks/vicki_arroyo_let_s_prepare_for_our_new_climate.html

In this Ted Talk, Vicki Arroyo, executive director of the Georgetown Climate Center, stresses taking action now to adapt to our changing climate. She explains climate change and the negative implications the world faces, such as global warming and population extinction. Her talk outlines the greater context for a Green roofs use. Climate change is the result of poor energy use that in return led to increased carbon emissions. This talk will help explain the background information on why green solutions are needed, and how implementing solutions such as Green roofs on buildings will help prevent climate change.

Benfield, K. (2013, Feburary 20). The link between sustainable farming and sustainable communities. [Blog]. Retrieved from http://switchboard.nrdc.org/blogs/kbenfield/the_link_between_sustainable_f.html

Kaid Benfield is the director of Sustainable Communities, Washington DC, and an adjunct professor at George Washington University School of Law. In his blog, Benfield sheds light on Peaceful Belly, a 60-acre organic farm outside of downtown

Boise that is combating the food dessert crisis and bringing the healthy, local, and urban aspects back into their food. The farm strives to be a model of ethical, sustainable practices, stressing the operation's strong commitment to community. The farm also offers classes and workshops on how to grow healthy food and how to cook with fresh local food, an on-farm dinner series called Farm to Fork. This blog highlights how we can engage the community by educating Easton and the College campus of our Green roof technology.

Benfield, K. (2012, October 10). Urban farm grows more than food as kids gain work, leadership skills. [Blog]. Retrieved from http://switchboard.nrdc.org/blogs/kbenfield/urban_farm_grows_more_than_foo.html

Co-founder of the LEED for Neighborhood Development rating system and the Smart Growth America coalition author Kaid Benfield named one of "the most influential people in sustainable planning and development" by the Partnership for Sustainable Communities created this blog. In this blog, Benfield showcases the urban Youth Farm that has created a curriculum that includes lessons on sustainable agriculture, cooking, communication and team- building, economics, nutrition and community health, food systems, and the agricultural history of the region. Over the 19-week program, youth participants learn a variety of skills related to growing, cooking and selling organic vegetables and fruit, ultimately growing over 7,000 pounds of food, donating a third to needy families, and expecting to produce 40,000 pounds by the year 2014. This blog highlights how education can play a major part in connecting our Green roof with the youth of Easton.

Benfield, K. (2013, March 7). World's second-largest rooftop farm takes root in Boston. [Blog]. Retrieved from http://switchboard.nrdc.org/blogs/kbenfield/worlds_second-largest_rooftop.html

This article is about the Higher Ground Farm, Boston's first rooftop farm, and at an acre in size, the second largest Green roof in the world. Higher Ground plans to use organic methods when growing their assorted fruits and vegetables for the Boston community, selling goods through community-supported agriculture shares and non-profits to local restaurants and corner stores. Benfield highlights how the Higher Ground Farm contributes fresh food and ecological benefits to the urban environment while not interfering with the density and ability to navigate Boston. We can learn from the Higher Ground's rooftop farming infrastructure and how they plan on localizing organic food production on rooftops while still placing it in a modern context.

Foster, S., Sullivan, S., & Freitag, K. (n.d.). Regional Plant List - New York, NY, Pennsylvania, PA, Northern New Jersey, NJ. *PlantNative - Native Plants, Lawn Alternatives, Landscape Design and Landscaping*. Retrieved March 16, 2013, from http://www.plantnative.org/rpl-nypanj.htm

PlantNative is a company located in Portland, Oregon dedicated to spreading the use of native plants in landscaping projects because it promotes biodiversity and

enhances landscaping projects' survival rate. Steve Sullivan is the director, Sarah Foster is the website designer, and Kris Freitag is the botanist of this business. Although Plant Native is in Portland, Oregon, these three business partners work with nursery owners and landscape professionals around the country to spread awareness on the benefits of using native plants in their landscaping projects. The company's website is filled with native plant lists for every State in the United States including Pennsylvania. The website also has contact information for the plant nurseries in the area if we needed additional information on biodiversity or native plants for our Green roof project.

Green roofs Benefits and Cost Implications. (2004). *Birmingham Eastside sustainable regeneration project*. Retrieved March 10, 2013, from http://www.sustainable-eastside.net/Green%20Roofs%20Report%202.07.05.pdf

Sustainable Eastside is a business alliance whose intent is to encourage those involved to participate in sustainable practices. They hired livingroofs.org and Ecology Consultancy Ltd to compare the cost and benefits of a Green roof with those of a conventional roofing system. The Sustainable Eastside Business Alliance distributed the resulting report to enlighten professionals about Green roofs and to clear up any misconceptions they may have about this relatively new technology. Since my team and I would like to design a Green roof at Lafayette College, the "Cost" portion of the report will prove to be valuable. We understand that the report was intended for a "British market" which prevents us from using sections like *6.2 Ball Park figures for costs* and its policy portion. However, we would still be able to obtain a general sense of the costs involved with Green roofs.

Harrold, K. (2012, May 31). Engaging the senses [Weblog Comment]. Retrieved from: http://www.greenrooftechnology.com/_blog/green-roof blog/post/Engaging_the_Senses/

This blog entry explains Green roofs' interaction with the five human senses. While this may seem somewhat trivial, the blog gives valuable insight into the total effect a Green roof can have on human perspective. All possible senses are explored, giving a look into the overall experience a Green roof can create. The author, Kat Harrold, is one writer amongst many from Green roof Technology Blog, a blog covering recent and past developments in Green roof technology. The blog is comprehensive and is filled with valuable articles. The site will likely be used again, for many case studies are present on the blog. The blog is helpful in regards to exploring non-professional perspectives, and will give insight into how a community such as Easton may view a Green roof.

Pawlyn, M. (2010, November). Michael Pawlyn: Using nature's genius in architecture [VideoFile]. Retrieved from http://www.ted.com/talks/michael_pawlyn_using_nature_s_genius_in_architecture.html

In this Ted Talk, Michael Pawlyn, founder of the Exploration architecture firm, argues that designers should be looking to nature for their designs. Nature, as Pawlyn

explains, has pre-existing designs that have been around for millions of years. He uses examples such as the wing of an insect to illustrate the beauty, simplicity, and sound structure of nature's design. For years, humans have been working against nature, attempting to develop designs of their own. Instead, designers need to return to their roots and begin designing with nature as the archetype. This talk reinforces the use of Green roofs in design, for they are as roofs as nature intended them to be.

Velazquez, L. S. (n.d.). Greenroofs.com: Sky Gardens - Travels in LA Archives 0504. *Greenroofs.com: The Resource Portal for Green roofs*. Retrieved March 17, 2013, from http://www.greenroofs.com/archives/sg_may-jul04.htm

Linda Velazquez, an American Society of Landscape Architects Associate, wrote this blog entry so the reader can obtain an understanding of the "Green roof movement" in Pennsylvania. She writes about the storm water run-off issues in the state's big cities like Philadelphia and Pittsburg and how they lead to combined sewer overflows. This issue has inspired many non-for profit organizations, local architects, civil and environmental engineers, and Pennsylvania Colleges and Universities to take part in the Green roof movement. The blog then lists examples of Green roofs that have already been installed in Pennsylvania. The article ends with a list of descriptions and contact information for architects and designers of Green roofs in Pennsylvania.

This article gives us a contextual sense of Green roof technology in Pennsylvania. It explains how the movement started and who is giving the Green roof movement momentum in the state. The list of architects and designers of Green roofs will also prove to be valuable when designing our Green roof.

Appendix B:

Vegetation:

We decided to choose a combination of Sedum, Delosperma, Talinum and Alium because they are hardy plants that can survive constant sunlight, short droughts, and shallow soil. When deciding to choose plants for our Green roof we considered its Hardiness Zone. This is a geographically defined area determined the United States Department of Agriculture that specifies what plant life is able to grow there. Each zone is given a number and letter combination from 0a to 12b and you must grow plants that are labeled with the same number and letter combination or less. Easton is in a 6b hardiness zone so all the plants can survive in hardiness zone of 6b or less.

The plants chosen can bloom anywhere from late spring to late summer. The flower color are a play of Lafayette College's colors and range from pink to purple mixed with white and gold. During the winter the Sedum turn a dark red or bright green and the other vegetation stays dormant until the next blooming season. A complete list of the flowers, their blooming season, flower color, and winter color can be found below:

Sedum Acre
Flower Color: Gold

Blooming Season:: Early-Mid Summer
Winter Color: Bright Green

Sedum Album
Blooming Season: Midsummer
Flower Color: White
Winter Color: Red

Sedum Album “Murale”
Blooming Season: Midsummer
Flower Color: White
Winter Color: Red

Sedum Spurium
Flower Color: Red with Green
Blooming Season:: Mid Summer to Late Summer
Winter Color: Red

Delosperma Dyeri
Flower Color: Red
Blooming Season: Midsummer to Mid Autumn
Winter Color: Purple

Delosperma Nubigenum
Flower Color: Yellow
Blooming Season: Late Spring
Winter Color: Pink/Red

Allium Schoenoprasum
Flower Color: Pink to Lavender
Blooming Season: Mid Spring to Early Summer
Winter Color: Dormant

Talinum Calycinum
Flower Color: Pink, Red

Blooming Season: Mid Summer
Winter Color: Dormant

Growing Medium:

The soil/medium required for the Green roof needs to be lightweight, versatile, highly water absorbent, and most importantly easy to maintain. Resultantly, an engineered blend of natural loam - a soil moderate in clay, silt, and sand - and synthetic lightweight soil is our recommendation. When purchased the media should be sterile of all weeds and should have a 75% to 80% mineral content with only a 20% to 25% of organic material. The plants selected for this project enjoy dry, mineral filled soil so a high percentage of organic material is not necessary.

The growing medium must consist of a range in grain sizes to provide sufficient drainage while allowing some water retention to ensure water availability to plants. If the medium is too granular, water is lost too quickly and plants may suffer from water shortage.

The depth of the New Williams Art Center Green roof medium will be 4 inches deep.

Filter Fabrics:

We recommend placing a layer of filter fabric over the drainage layer to prevent particles from the growing medium from clogging drainage paths.

Drainage Material:

Green roofs are meant to retain about one inch of rainfall. If more water is retained, then the plants will experience anaerobic conditions and potentially die. To maintain the appropriate amount of water retention in the New William Arts Center Green roof, we recommend installing drainage panels as cones filled with small diameter, pre-washed river rocks. This system will facilitate the drainage of excess water.

Insulation:

We suggest a polystyrene thermal insulation layer for the New William Arts center building. Polystyrene is a petroleum-based product that can be purchased in two variations: xPs which are Polystyrene boards and EPs which are block-molded polystyrene. Boards are most commonly used for insulating Green roof decks because they are lightweight, dense, and hydrophobic. A board is usually produced in a 2-foot-by-8-foot or 4-foot-by-8-foot sizes and in thicknesses of 1 to 5 inches. xPs can also be handled by one person and cut on the field.

Our team decided to place the insulation layer above the water proofing membrane layer in order to provide it with extra protection. This arrangement of the Green roof layers also decreases the chances for condensation build up. The only problem with this arrangement is that it can hinder Green roof drainage. This can be fixed by pitching the insulation layer 1% towards the roof's drain.

Protection Board:

During construction, the waterproofing membrane is vulnerable to damage**.** We recommend placing one-quarter inch semi rigid sheets of cement board over the membrane for protection. This layer can either be kept or removed after construction.

Waterproofing:

Our team recommended a single-ply (PVC) waterproofing membrane. Single-ply membranes average a serviceability of 10 to 15 years which is doubled with the protection of a Green roof. An advantage in using a single-ply system is that they are faster to install and require less labor than built-up systems. Because of their characteristic flexibility, they are less susceptible to cracking and seam failure. When you combine their flexibility with the fact that single-ply membranes require fewer seams, the risk for leaks is reduced. The rubber is also resistant to root penetration meaning our Green roof system will not require an additional root barrier. PVC membranes are considered easy to install and comparatively low-cost. They are able to withstand temperature extremes and do not become brittle nor melt.

Single-ply PVC membranes are bought in large rolls and then rolled out onto the required surface. They seams are then heat-welded together and adhered to the surface of the roof.

Because of the importance of the waterproofing membrane, We recommend that Professor Mary Wilford Hunt and her team check with a waterproofing expert or consultant.

Irrigation:

A system for consisting watering is not necessary for this selection of plants. The vegetation should be top watered with a sprinkler once a week for the first couple of months so the plants can take root. After that, the hardy plants chosen for this project prefer dry conditions and should be watered once every two months. If a drought occurs, the plants should be watered once a month.

Maintenance:

The roof must plucked of weeds and other invading plants for the first year the chosen vegetation has the opportunity to take root. Once the plants have fully grown into their new environment, weeds have a tougher time taking root. This means the weed

would have to be plucked from the roof only twice a year for the remainder of the Green roofs life: once in the Spring and once in the Fall.

Loading:

There are two methods for determining the loading on steel structures:

- Allowable Design Strength (ASD)
- Load and Resistance Factor Design (LRFD)

Both of these methods provide a list of potential loading combinations consisting of: Dead Loads,

Live Loads, Roof Snow Loads, Wind Loads, Roof Live Loads, Wind Loads, etc. You check the loading for each scenario and design your steel structure using the heaviest loading. The difference between the two methods is the Load and Resistance Factor Design places a greater emphasis on live loads in the loading combinations. Since the dead load was much larger than the other loadings for the New Williams Art Center Green roof, we decided to use the Allowable Design Strength Method.
Our Loadings Were:

- Dead Loads: 496.5 psf (This weight includes the soil, concrete slab, drainage mat, insulation, and gravel)
- Roof Live Loads: 20psf (This includes the weight on the roof during its construction and maintenance)
- Roof Snow Loads: 30psf
- Wind Load: 30psf (Assumed Wind Load)

Relevant ASD Loading Combinations:

- Dead
- Dead + Live
- Dead + (Roof Live Load or Roof Snow Load)
- Dead + (0.75 x Live Load) + (0.75 x Roof Live Load or Snow Load)

The heaviest loading combination for the New Williams Art Center Building is Dead + Roof Snow Load
Final Roof Loading: 500psf