Prioritizing Sustainability Projects with Low Market Value in Institutions of Higher Education: a green roof case study

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DEDICATION

This is dedicated to all of those overworked, underpaid, passionate, tireless, under-resourced, beautiful people working for sustainability in higher education to change the world. You know who you are – go take a break from saving the world for a day or two.

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ABSTRACT

PRIORITIZING SUSTAINABILITY PROJECTS WITH LOW MARKET VALUE IN INSTITUTIONS OF HIGHER EDUCATION: A GREEN ROOF CASE STUDY

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This thesis adds to the body of knowledge available to decision makers in higher education by presenting a framework for why valuable sustainability projects are often not pursued on university campuses, and offers one approach to overcoming the perceived financial obstacles for making investments in sustainability projects. The framework is tested and verified through the evaluation of the benefits and costs of a green roof case study at George Mason University in Fairfax, Virginia. It is concluded that the traditional approach to cost-benefit analysis is woefully insufficient at assessing the true value of sustainability projects in higher education. However, with the inclusion of valuing the environmental and social benefits of these projects, cost-benefit analysis not only becomes more accurate, but the process itself can catalyze latent interest in the use of sustainability projects to enhance teaching and research. Therefore, establishing standardized processes and communication methods to support the conduct of a cost-

benefit analysis of any sustainability project in higher education are critical components to ensuring the success of the exercise.

1. Introduction to the Problem

A 2004 survey was conducted among 11 Boston-area universities regarding their sustainability practices. The results showed that they all responded in the same way when asked what their criteria would be for adopting or rejecting sustainable ("green") practices: savings and costs. This was evidenced by their common practices around construction waste recycling, white paper recycling, and water conservation (Biemiller, 2005). This focus on savings and costs is not atypical. Many higher education facilities management trade articles highlighting the benefits of campus greening emphasize the great savings or cost avoidance that can occur as a result of conservation measures or efficiency improvements (Morris, 2005; Levy & Dilwali, 2000). Although many universities are realizing the *financial* benefits that may be captured through efficiency improvements in operations, fewer recognize the *non-financial* benefits resulting from sustainability projects that may be captured as institutions of higher education. As a result, university budget offices and facilities decision makers may avoid projects that may have an overall net benefit to the university community.

One example of a sustainability project that generates both financial and non-financial benefits is a vegetated (or "green") roof.[1] Green roofs are still relatively uncommon in the United States, representing only about 9.7 million square feet of roof area, or about 223 acres. Of this, only about 8.3 acres are on college and university

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[1] See Appendix A for a broad overview of green roofs.

campuses. [2] There are several reasons for slow adoption of green roofs in the United States, among them a simple lack of understanding and awareness, increased initial investment, and the lack of technical data about how to install the roof. This creates enough of a deterrent to universities examining the possibility of installing a green roof (Getter & Rowe, 2006). Add to this the inability to financially quantify benefits like aesthetic improvement, creation of habitat, psychological health, community space creation, educational benefits, and image enhancement, and green roofs become a losing proposition for many higher education building roof owners.

While a variety of cost-benefit analyses have been conducted on the technical and financial benefits of green roofs, only a few have even attempted to quantify some of the social benefits of green roofs, like the improvement of health as a result of the reduction in local pollution (e.g., Carter & Keeler, 2008; Porsche & Kohler, 2003; Wong, et al, 2003; and Clark et al., 2007). The majority of *non-financial* benefits of green roofs – especially in the context of universities – have not yet been identified and quantified. This situation is reflective of other sustainability projects. A variety of tools exist to quantify the benefits of sustainability projects, including those that use a combination of financial measurement and weighting or ranking schemes (Tanzil, et al, 2007), but none provides guidance for the pure financial assessment of the social and environmental values resulting from investment in sustainability projects.

This thesis adds to the body of knowledge available to decision makers in higher education by presenting a framework for why valuable sustainability projects are often

[2] These are only estimates, as taken from the International Green Roofs Database. If projects have not been registered, they would not be counted in the total. http://www.greenroofs.com/projects/plist.php

not pursued on university campuses, and offers one approach to overcoming the perceived financial obstacles for making investments in sustainability projects. The framework is tested and verified through the evaluation of the benefits and costs of a green roof case study. In a university setting, where education and research are the key missions of the organization, this thesis illustrates how investment in sustainability projects may influence the institution's financial solvency, but also its reputation, which has potentially significant long-term benefits to the institution.

In order to provide the context and backdrop for this analysis, the history and relevance of sustainability in higher education is discussed. The theory behind why all universities might not choose to pursue sustainability strategies is then reviewed within the framework of an information asymmetry model. In order to illustrate how the benefits of sustainability projects often outweigh their costs, a cost benefit analysis is performed for a green roof at George Mason University in Fairfax, VA. Finally, the results of this analysis and their implications for decision making about sustainability projects in higher education are discussed, as are areas of future study.

2. **The history and institutional relevance of sustainability in higher education**

The United Nations Conference on the Human Environment (known as the Stockholm Conference, in 1972) publicized the notion that environmental health directly influences the socio-economic health of human society. (UNEP, 1972) The conference acknowledged that incorporating sustainability principles in education was as a critical influence on sustainable development.[3] Subsequently in 1990, Talloires, France hosted the first formal effort to organize leaders of higher education toward common goals of sustainability, which resulted in the Talloires Declaration[4]. At this meeting, participating university leaders asserted that:

> *Universities educate most of the people who develop and manage society's institutions. For this reason, universities bear profound responsibilities to increase the awareness, knowledge, technologies, and tools to create an environmentally sustainable future.*

Sustainability in higher education therefore plays a critical role in the overall sustainability of global economy, environment, and society (Talloires Conference, 1990). Anthony Cortese summed up the importance of sustainability in higher education by stating: "Higher education institutions bear a profound, moral responsibility to increase

[3] Principle 19: "Education in environmental matters, for the younger generation as well as adults, giving due consideration to the underprivileged, is essential in order to broaden the basis for an enlightened opinion and responsible conduct by individuals, enterprises and communities in protecting and improving the environment in its full human dimension (UNEP, 1972)."
[4] University Leaders for a Sustainable Future, accessed 2/09: http://www.ulsf.org/programs_talloires_td.html

the awareness, knowledge, skills, and values needed to create a just and sustainable future (Cortese, 2003)." This influence was recently reaffirmed through the 2005 United Nations resolution that created the "Decade of Education for Sustainable Development."

The history and growth of the recognition of the importance of sustainability in higher education is a reflection of a university's *institutional environment*. An institutional environment is defined as "a composite of constituents within the firm's external social, political, and economic environments." As such, an organization is "bound by social influences, embodied in rules, laws, industry standards, best established practices, conventional wisdom, market leadership, and cognitive biases." (Hoffman, 2001) There are several emerging trends within a university's institutional environment that have encouraged the inclusion of sustainability as an aspect of university planning. First, a number of professional higher education publications and organizations have begun to include sustainability as one of their main focal themes. Second, there has been a proliferation of ranking and weighting schemes measuring various aspects of campus sustainability. Third, institutions have been able to distinguish themselves locally or regionally as community stewards or "market leaders" by implementing innovative sustainability projects that answer local or regional needs, like green roofs.

In the realm of university administration, professional organizations have placed sustainability alongside other critical issues for higher education in recent years. For example, the Society for College and University Planning sponsors Campus Sustainability Day each year, and hosts an ongoing "knowledge community" discussion forum about campus sustainability in relation to planning.[5] The National Association for College and University Business Officers now sponsors a Sustainable Campuses conference every year, and supports research publications around campus sustainability practices.[6] In addition, professional organizations and consortia dedicated to the study and dissemination of best practices for sustainability in higher education have emerged in recent years.[7] As an example of the growing interest of institutions in these issues, membership in the premier organization for sustainability in higher education (the Association for the Advancement of Sustainability in Higher Education, or AASHE) has risen from 250 universities in 2005 to 830 in 2008, illustrating an increasing interest in sustainability in higher education (Webster and Dautremont-Smith, 2009).

One way to compare a university's environmental performance is by comparing it to its peers through voluntary classification schemes. Environmental indices have been added to some traditional educational ranking sources that students and their parents examine when choosing an institution, such as the Princeton Review and Peterson's Guide. Environmental non-governmental organizations like National Wildlife Federation's Campus[8], Sierra Club Magazine[9], Sustainable Endowments Institute[10], and

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[5] http://www.scup.org/page/resources/topic-issue/sustainability (accessed 8/28/09)
[6] http://www.nacubo.org/Business_and_Policy_Areas/Sustainability.html (accessed 8/28/09)
[7] Independent organizations include University Leaders for a Sustainable Future (ULSF), Association for the Advancement of Sustainability in Higher Education (AASHE), National Wildlife Federation's Campus Ecology Program, and the Campus Consortium for Environmental Excellence (C2E2). Consortia include the Disciplinary Associations Network for Sustainability (DANS) and the Higher Education Associations Sustainability Consortium (HEASC).
[8] NWF's Campus Ecology's "Campus Report Card": http://www.nwf.org/campusEcology/campusreportcard.cfm
[9] Sierra Magazine's "Cool Schools": http://sierraclub.org/sierra/200909/coolschools/default.aspx
[10] Sustainable Endowments Institute's "College Sustainability Report Card": http://www.greenreportcard.org/

AASHE[11] are providing opt-in mechanisms through which universities can share their sustainability efforts and enable them to be compared to other institutions. These rankings are self-reported, and based on surveys distributed to campuses that choose to participate.[12] They enable administrators to qualitatively assess their progress on a standard scale against other institutions, but they do not aid them in assessing the costs and benefits of projects or initiatives supporting sustainability.

Third-party certification[13] of a university's environmental activities (for example, if the installation of a green roof provides the opportunity to gain US Green Building Council's LEED[14] certification on a building) may generate positive publicity that helps differentiate it from its competitors (Darnall & Carmin, 2005). Favorable rankings by respected independent third party publications may provide universities significant marketing opportunities that increase student applications, enrollments, and satisfaction rates, improve the university's ability to attract high quality faculty and staff, and enhance opportunities to attract grants and donations. Combined, these factors may increase the university's environmental image.

To the extent that a university can improve its environmental performance by way of green roofs or other sustainability activities, it could lead to improved community citizenship for the university. For further analysis of the institutional environment of green roofs in the DC metro region, see Appendix B.

[11] AASHE's Sustainability Tracking, Assessment, and Rating System (STARS): The STARS tool defines campus sustainability using three major categories: education and research, operations, and administration and finance.
[12] Surveys were completed by the author for these rankings for George Mason University.
[13] Third-party certification is still opt-in, but a third party verifies the performance of some aspect of environmental performance, such as green building standards.
[14] Leadership in Energy and Environmental Design

In summation, there are some compelling reputational reasons for universities to pursue greening strategies, including the reduction of costs and the improvement or enhancement of university reputation (Morris, 2005). However, reputational benefits are not always easy to measure in market terms, which is why many universities fail to implement strategies to capitalize on the benefits of "going green."

3. Quantifying the benefits of sustainability projects

Projects associated with sustainability programs create two kinds of benefits: *market* (direct and indirect) and *non-market* (or externalities). The ease by which these benefits can be quantified falls on a continuum from easy to difficult. The total benefits reaped from a sustainability project can therefore be defined as:

Total benefits = Direct and Indirect Market Benefits + Non-Market Benefits

Market benefits are direct benefits that "represent the increased value of physical (real) goods and services" (Fuguitt & Wilcox, 1999, p. 167). Related to sustainability projects, market benefits are usually reaped through efficiency improvements due to reductions in the consumption of electricity, fuels, water, and other consumable resources used during the course of normal operations (Pearce & Miller, 2006). Capturing the financial savings relating to efficiency improvements can create a long-term competitive advantage for universities willing to pursue "economically efficient" greening strategies.

When a university implements sustainability projects, such as installing a green roof, they see energy savings through improved temperature regulation at the rooftop level. These benefits are clearly measurable through the market. In winter, energy may be saved through the additional insulation provided by the plantings. In the summer, energy may be saved through the regulation of the roof temperature via evapotranspiration (Liu & Baskaran, 2003). The lengthening of the roof life through protection of the membrane is another market benefit associated with green roofs. Adding a green roof can double the life of a roof, from 20-30 years to 40-60 years or more, if installed correctly (Peck and Kuhn, 2000; Acks, 2006). When the cumulative market benefits over the life of a green roof (or any sustainability project) are at least as great as the costs of the project, there is rationale to implement it. However, there are also indirect market and non-market benefits associated with these projects that should be considered (Bardaglio & Putnam, 2009).

Indirect market benefits have dollar values that cannot be immediately determined.[15] The indirect market benefits of a green roof, for example, might include avoided maintenance costs of traditional stormwater management systems resulting from the implementation of on-site stormwater management methods. Additionally, universities may increase their access to grants that encourage sustainable technology development and testing. Alumni or other private donations may increase, as well.

Finally, *non-market benefits* – benefits most often associated with environmental products and ecosystem services – are benefits that are not traded on the open market, and thus have no obvious dollar benefit. These are also called positive externalities. [16] Examples of the potential non-market benefits created by a green roof include increased green space, habitat for local wildlife, improved water quality (Dunnett & Kingsbury, 2004), improvement of human health through reduction of pollutants (Clark et al, 2007),

[15] Fuguitt & Wilcox suggest that indirect benefits not be assessed when conducting a CBA, because an indirect benefit accruing to a project is generally diverted from other sectors of the economy, returning a net zero benefit to society as a whole. However, because we are most interested in determining the impact on the campus community (or at the regional or local level at broadest), we have decided to include indirect market benefits of things like grants and donations acquired as a result of the green roof.

[16] *Externalities* are defined as byproducts of any activity – either positive (defined as a non-market benefit above) or negative (cost) – that are not captured by the producer and thus not captured in the final market price of the product resulting from the activity. This means that the organization has "externalized" some of the costs (or benefits) as a by-product of its operations (Turner et al, 1993, p. 25).

and improvement in sustainable global development through the encouragement of interdisciplinary research (Kleniewski & Wooding, 2002; Stiglitz, 1999). Other potential benefits include enhanced community support and partnering opportunities (Braskamp & Wergin, 2002), greater educational opportunities, improved ability to recruit higher quality educators, and enhanced academic reputation. These non-market benefits are valuable to the long-term reputation of the university.

Studies have shown that reputation is an intangible asset that can be translated in to a significant economic impact on companies in the S&P 500 (Konar & Cohen, 2001). While companies' environmental reputations are affected by positive (e.g., environmental awards) and negative (e.g., accidental toxic releases) environmental incidents, the environmental reputation of a university relies on how its overall sustainability portfolio (including both operational performance and research and education) compares to other universities within their institutional environment. For example, although there are market benefits to installing a green roof, the visibility of a green roof can contribute to a university's reputation of being a committed environmental steward.

While university decision makers acknowledge that indirect and non-market benefits exist, they often fail to consider them in a serious way because of *information asymmetries* in the university context.

4. Why universities fail to allocate resources to sustainability: Information asymmetry in the university context, and a framework for overcoming it

When decisions about university sustainability projects are made solely on market information, and indirect market and non-market benefits are not considered, university resources may not be efficiently allocated. University resources include a direct outlay of cash, as well as other resources available to the university community, such as staff, faculty, and student time and access to technology or equipment (Velazquez et al, 2005). In a university, the main reason for the misallocation of resources in relation to sustainability is *information asymmetry*, which leads to the unwillingness to pay for the creation of positive externalities (Stokey & Zeckhauser, 1978).

Information asymmetry is defined as the *imperfect flow of information*. It occurs when buyers and sellers do not have the same information about the goods being sold on an open market (Stokey & Zeckhauser, 1978). While not technically an open market, the same concepts may be applied to the failures that occur when allocating resources among university projects and programs. These failures arise when sustainability projects and programs are devalued because decision-makers lack information.[17] For example, the funding to create a green roof may compete with the funding for a new arts program. If

[17] This is also true for most other resource allocation decisions at a university, where decision making about resource allocation is at best an educated guess. According to James (1990), this occurs because decision-making is based on an attempt on the part of the recipients to maximize the utility of their individual/department although they may in fact conflict with the priorities of the university at a strategic level. (p. 95-105)

the university already has a positive reputation in the arts, and it does not have ample information to assess the full value of a green roof, it may fund the arts program, without realizing the additional benefits a green roof provides to the community. When trying to build support for cross-functional sustainability projects of all kinds, and especially at a university, many barriers may be encountered to sharing (both receiving and obtaining) information. These barriers prevent critical questions from being answered that would enable the accurate assessment of sustainability projects. It is this lack of information transfer that leads to internal information asymmetry and the devaluation of sustainability initiatives.

There are five types of internal information asymmetry that obstruct universities from investing in sustainability programs: conceptual, organizational, knowledge transfer, technical, and economic (Dieleman & de Hoo, 1993; Cordano & Frieze, 2000).

4.1. Conceptual issues

Conceptual issues leading to internal information asymmetry can be described as differences in understanding (or lack of understanding) among members of the same organization when considering the same issues. In such instances, not every university stakeholder has the same information about how a sustainability project may benefit them, their constituents, or the community at large. Conceptual internal information asymmetry manifests itself as a general lack of information, misinformation, or a misunderstanding of the processes, technologies, and purposes of a green roof or any other sustainability project. This in turn may be influenced by "one's training… working experience and… political and economic setting (Filho, 2000)."

There are several difficulties with incorporating sustainability concepts into the general culture and knowledge of the campus community. First, there is often an unintentional cultural exclusivity attached to the understanding of sustainability which serves to further stratify and segregate the campus community (Onwueme & Busari, 2007). The second difficulty relates to a general lack of common understanding about what it means to be "sustainable" (Velazquez et al, 2005), and how sustainability fits into the priorities of the university.

Faculty and graduate students at universities gain recognition through research and publication (Balderston, 1990). In order to attain tenure, faculty must remain focused on areas in which they may already publish. Because most academics have no formal background in environmental or sustainability issues, it can be very time-consuming to integrate these topics into their publications and lectures (Boyle, 1999).

Without the academic or cultural will to overcome them, these conceptual issues can lead decision-makers to draw mistaken conclusions that sustainability initiatives' costs are higher than their benefits, irrelevant to the mission of the university, impossible to implement, or undesired by the campus community. These issues often cause university leaders to under-value sustainability projects, and favor programs like environmental health and safety, whose market costs are easier to understand and quantify (Hart, 2005).

4.2. Organizational issues

Organizational issues that create barriers to information disbursal are caused by organizationally distributed decision-making processes for budgeting, compartmentalization of functions, and incorrect placement of sustainability offices in the decision-making hierarchy. Universities can be described as "… 'loosely-coupled systems,' characterized by the high degree of autonomy of sub-systems like departments or faculties" (Weick, 1976; Albrecht, 2007). Decision-making in universities is highly decentralized, sometimes being referred to as 'organized anarchy' (Cohen & March, 1974).

Resource allocation at the administrative level is not always effective in meeting the strategic goals of the university, even when one of its strategic goals happens to be centered on sustainability. Often, decisions made by one department do not take into consideration the costs or benefits this decision may have on other departments. In addition, the sometimes-conflicting goals of various departments are not transparent to the financial decision-maker (James, 1990).

Sustainability projects frequently benefit the university in broader strategic ways where the benefits cannot be "assigned" to one department or another. Since academic departments compete for a limited pool of funding, they are unlikely to champion the provision of funding for university-wide projects that do not directly benefit their research or status (James, 1990). With limited resources, faculty and deans are often confronted by tough resource allocation decisions, and they often default to areas in which they can be assured success. Additional challenges are created by the differing goals of facilities staff and academics. The goal of facilities staff is typically the provision of high quality products and services at the lowest possible cost,[18] whereas the goal of the Provost's office is to further the educational quality and reputation of the university.[19] This divergence of mission, and the fact that operations costs are typically seen as "opportunity costs" (i.e., money that could have been spent on research or education), can create a communication rift between faculty and facilities staff (Hoenack, 1990). However, this hurdle detracts from the overall success of the institutional mission. Indeed, universities that incorporate sustainability into their operational functions but fail to involve the faculty and students as part of the educational process can lose up to 75% of the value of its efforts (Cortese, 2003).

Additional compartmentalization exists across academic, operational, and student life functions. Because professionals from each area infrequently interact, they often do not understand the mission, goals, and in some cases even the function of the other two. Consequently, decision making across these boundaries can be confusing, requiring new processes to be established and new understandings to be obtained before any real work can be done, which may delay or entirely thwart an attempt at interdisciplinary projects (Velazquez et al, 2005). While academic, operational, and student service departments have regular staff meetings, it is extremely rare to have inter-departmental meetings (Herremans & Allwright, 2000). As a result, sustainability-related projects and programs within one department are often opaque to the rest of the campus community (Roturier & De Almeida, 2000).

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[18] Examples: University of Virginia Facilities Management page: http://www.fm.virginia.edu/, Virginia Tech facilities page: http://www.facilities.vt.edu/, University of Rochester Facilities and Services page: http://www.facilities.rochester.edu/

[19] University of Michigan Provost's Office page: http://www.provost.umich.edu/about/welcome.html

Finally, since sustainability projects often are implemented within university functional areas, (such as a facilities department) rather than at the executive level of the university, these initiatives generally lack an effective champion. For example, if the facilities department were to propose to undertake a significant sustainability project such as the construction of a green roof, it would need to explain to each department how doing so would benefit their programs. It would be extremely unusual, however, for a single departmental champion to have all the necessary knowledge and influence to pragmatically assess and convince individuals within other departments of the value of the project. Even if a university-wide committee is assembled to address funding matters in relation to the green roof, the unique nature of the project and a lack of a consistent evaluation process slows and potentially thwarts the project.

4.3. Knowledge transfer issues

Knowledge transfer issues result from the diversity of university stakeholders often required to implement successful interdisciplinary sustainability projects. These issues are created by differing communication styles and ways of seeing the world.

Universities are filled with experts with their own cognitive models for viewing the world. Even in groups that have similar backgrounds and experience, defining the problem so that each member understands it in the same way can be a challenge. Often, "representational gaps" occur in problem-solving groups as a result of the process of creating a joint representation of a problem. The underlying individual assumptions, ideologies, and cognitive abilities of its members drive the creation of that representation. Without the ability to truly understand the problem from one common viewpoint, well-meaning individuals thwart consensus among a team working to solve it (Cronin & Weingart, 2007).

There are even greater challenges associated with the interdisciplinary teams often required for sustainability projects. Rifts in understanding and societal standing between social and natural scientists may contribute to problems when working on sustainability projects. Embedded-ness of value judgments, differing underlying theories and explanatory models, and fundamental differences in assumptions can create an impassable situation when attempting to arrive at consensus (Lele & Norgaard, 2005). Sustainability is a perfect example of a situation where university excellence cannot occur without the work of cross-functional teams. In addition, the university tenure system often requires faculty to decide, at least in the short run, between collaborating with peers in other fields toward a common goal for the university, and their own career aspirations.

4.4. Technical issues

Technical issues leading to internal information asymmetry in sustainability relate to the adoption of new technologies like green roofs. Managers are often skeptical of new technologies and knowledge until they have proven their worth and safety at other institutions first (Dieleman & deHoo, 1993). The natural human resistance to new processes and methods may be faulted in this lack of adoption (Dresner, 2002; Velazquez et al, 2005).

A facilities department's goal is not to innovate, but to provide safe and working structures for the campus community, while minimizing operating costs. Thus, they generally avoid untested and expensive technologies. For instance, although green roofs are becoming more popular and well-accepted as a common green building practice, many facilities managers are still concerned about their viability. This concern usually stems from a lack of information and education, questions about additional maintenance costs, capital financing barriers, and zoning and building codes (Clune & Braden, 2007). Misgivings regarding the implementation of a green roof are mostly based on outdated information, as technology has advanced to the point where, when installed correctly, green roofs have a longer life and a greater integrity than standard roofing. Facilities managers are often not aware of successful projects at peer institutions unless those institutions seek media coverage for their successes.

In addition, facilities decision-makers may also simply lack the knowledge to assess whether these solutions are feasible in a particular instance. Such knowledge gaps can lead to potential problems during project implementation, which subsequently discourages these decision-makers from undertaking future sustainability projects as well. One poignant example comes from Pennsylvania State University, where permeable asphalt[20] was used to decrease stormwater runoff. The asphalt did not work correctly because it was incorrectly installed. As a result, the facilities department has indicated thatit will "never install [permeable asphalt] again." By contrast, the same university's Center for Green Roof Research has become a center of excellence in green roof

[20] Permeable asphalt is a new technology which replaces standard asphalt in low-weight and low-traffic conditions, enabling water to percolate through the surface instead of flowing over the top and into storm sewers.

scholarship as a result of an extremely successful roof installation early on in the life of the program.[21]

Often, technical expertise regarding new technologies is only available through consultants that specialize in installing these technologies. This technical barrier potentially creates yet another hurdle, as the consultant services often must be placed out for bid before any services or expertise can be secured.

4.5. Economic issues

Finally, *economic issues* leading to internal information asymmetry are barriers to the adoption of sustainability projects. Universities are non-profit organizations. This means that academic and operational departments vie for the same limited resources, sometimes at the expense of the greater benefit of the university (James, 1990). Additionally, universities may have difficulties obtaining financing for increased capital funds that can be allocated towards green technologies. The reason for these difficulties relates to the fact that financiers are often unaware of the long-term benefits of green technologies, and unwilling to pay for the additional capital costs (Clune & Braden, 2007). This is changing, however. As an example, recently the Commonwealth of Virginia has begun to take building lifecycle (or operating) costs into account when allocating funds for new buildings.[22]

With respect to new buildings, the occupant can be yet another hurdle for long-term financial decision-making. Since the occupant of the building is typically consulted

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[21] Interview with Dr. Berghage from Pennsylvania State's Center for Green Roof Research.
[22] Discussion with Vice President for Facilities, George Mason University, in regards to changing capital allocation practices in the Commonwealth of Virginia.

during the design process, uneducated occupants often eliminate green features. Complicating matters is that university administrators often do not challenge the occupant to make an economically sound decision about the long-term economics of a green building.

A cross-functional budget committee, chaired by leadership from the budget office, handles budget governance at some universities. It is this structure of shared governance that gives sustainability initiatives a greater chance of success than more hierarchical decision- making structures. However, sustainability is a fairly new concept, and one that challenges historical methods of budgeting since its benefits generally accrue across multiple university functions.

In summation, internal information asymmetries prevent university decision makers from being able to accurately comprehend and assess the indirect and non-market benefits associated with sustainability projects. The overall result is that sustainability projects that have a higher net benefit to the university are foregone for more traditional academic program expansions or operational upgrades.

4.6. Cost Benefit Analysis as a Tool to Overcome Information Asymmetry

One method to overcome these information asymmetries and to answer the questions that allow indirect and non-market benefits to be accurately assessed is to leverage cost-benefit analysis. *Cost-benefit analysis* (CBA) is a decision-making tool used to assess the efficiency of any policy or solution that affects the use of scarce resources, where an efficient policy is defined as a process or investment that results in more benefit to *society* than cost (rather than to private parties or businesses). CBA is typically used when the outcomes of a policy are possible to quantify. Generally speaking, CBA is used to assess the value of one policy, by assessing its positive and negative effects on society at large (Fuguitt & Wilcox, 1999). Just as in government policy decision-making, limited funding drives the need to accurately assess the societal value of university projects, including those tagged as "sustainability" projects. CBA may be used to evaluate projects that produce substantial indirect market and non-market benefits that may not show an obvious market benefit over another project, putting sustainability projects in the running where they may not have been otherwise.

4.6.1. Discount rates and inflation

In order to capture the fact that the value of a dollar today is more highly valued than a dollar in the future (called *time preference*), all future cash flows should be discounted (Turner et al, 1993, p. 97). Selecting the incorrect societal discount rate can greatly affect the total value of the green roof. A mistake in setting the discount rate can cause the roof to be rejected when it should be accepted, and vice versa. As a result, there is always controversy around how to select a discount rate. A smaller rate is more equitable to future generations, because it means the value of the dollar is closer to being the same today as it is tomorrow.

4.7. Sensitivity Analysis

Under the condition where the value of some input variables (in this case the value of each cost and benefit) are uncertain, a tool called *sensitivity analysis* is commonly used. Sensitivity analysis allows the analyst to provide a range of potential

CBA outcomes based on varying values of costs or benefits (Fuguitt & Wilcox, 1999). Sensitivity analysis uses three possible levels of valuation to show the decision maker a "worst-case" scenario (Low), a "likely" scenario (Medium), and an "unlikely but possible best-case" (High) scenario. Uncertainty may be due to a lack of ability to predict, for example, the price for carbon offsets over the long horizon that we have selected, or it may be due to a dramatic range of results in other studies, making it difficult to select one value. Differing potential values of costs and benefits may change the final decision on whether a sustainability project is cost-effective. In addition, the sensitivity analysis is performed for several discount rates when conducting the net present value calculation, as discount rates are known to also impact the final value assigned to a project.

4.8. Benefit Transfer Methods

Benefit transfer is "where information on the value of environmental goods and services generated in one context is used to value similar goods and services in a different context (Ready & Navrud, 2005, p. 195)." Benefit transfer uses a number of studies that have calculated the costs and benefits of a particular green roof elsewhere and applies these costs and benefits to another location, which is referred to as the "policy site." Benefit transfer methods are useful when a study already exists that values the good in question. The biggest problem with this method is transfer error. Transfer error refers to the difference between the value of the good in previous studies and the value of the good at the proposed policy site. The magnitude of transfer error is an issue when it can mean the difference between one policy option and another. (Navrud, 2000) Studies have shown that transfer error is smallest when using studies that focus on a similar region. (Ready & Navrud, 2005)

CBA, informed by benefit transfer and sensitivity analysis, was used as the basis for developing a model to measure the value of university sustainability projects and to overcome the information barriers previously discussed. This model was applied to a green roof case study on the campus of George Mason University in Fairfax, Virginia. The approach and results of this approach are discussed in the next two sections.

5. Methods

The case study used to develop this framework was a green roof on the main campus of George Mason University in Fairfax, Virginia. While the university has made a commitment to green building by adopting the U.S. Green Building Council LEED Silver equivalent for all new buildings, it has avoided use of green roofs as a stormwater management tool for financial reasons. [23] While green roof benefits can arguably be geographically far-reaching[24], the scope of this study focuses on the campus community of George Mason University's main campus. Only costs and benefits potentially accruing to the Mason community are included in the analysis. The Mason community includes Fairfax City and County. The benefit transfer method was used to estimate the costs and benefits for our green roof "policy site." Selecting studies to use as data

5.1. Selecting green roof studies for benefit transfer

There are two types of modern green roofs. *Extensive roofs* or low-profile systems are typically installed for energy conservation and water retention values, and the vegetation best suited to those purposes is generally not meant for frequent foot traffic. Instead, plants are chosen for their functional value, and the soil medium is typically 4 inches or less in depth. Extensive roofs are low maintenance after their initial establishment period

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[23] See Appendix C for a more detailed description of Mason's expansion and its impact on the local community.
[24] As a result of the reduction of greenhouse gas emissions and air pollution.

of about 12 months. *Intensive roofs*, also called roof gardens, serve a more people-oriented purpose, creating meditative or social space in a natural setting. Intensive roofs may contain full-size trees, waterfalls or ponds, or even vegetable gardens, providing the ability to grow food in urban areas. Load requirements for intensive roofs are therefore much more significant and require irrigation and maintenance.

Studies evaluating extensive green roofs were included as a data source, because the costs of intensive roofs can be much greater. Additionally, intensive green roofs have the potential to reap benefits that extensive green roofs do *not* often reap (like community-building value for example). Although studies focusing on evaluating costs and benefits for a single green roof were preferred, there were found to be multiple studies conducted at a city-wide scale. Only some cost and benefit data could be used from these studies, because benefits accruing to cities implementing green roof policies are much larger and more complex than benefits accruing to private roof owners of a single roof. The implementation scale of these larger projects allows for the capture of benefits that do not appreciably exist with a single-roof installation (like urban heat island alleviation).

Table 1: Benefit Transfer - Location of Study Roofs

Author(s)	Location of Study Roof and Climate
Acks, 2006	New York City, NY – colder
Barreiro et al, 2005	Spain – hotter and drier
Clark et al, 2007	Ann Arbor, Michigan – colder
Carter and Keeler, 2008	Athens, GA – hotter
Peck et al, 1999	Toronto, CN - colder and wetter
Porsche and Kohler, 2003	Germany – colder and wetter
Wong, 2003	Singapore – wetter and hotter
Interviewee	**Location of Study Roof and Climate**
Dr. Robert Berghage, The Pennsylvania State University Green Roof Research Center, 2009	Philadelphia, PA – slightly colder

This thesis has attempted to use regionally specific studies to minimize transfer error. However, this proved to be difficult because there are a limited number of green roof studies. Therefore, values from more distant studies were used. Table 1 shows how climate differs between the case study site in northern Virginia and the sites of the other studies. Using sensitivity analysis reduced the bias created by non-regional data.

In order to determine the appropriate values to assign to each cost or benefit for the case study roof, each was collected and listed by author. Then, each cost and benefit was converted in to a common measurement unit of incremental annual dollars per-square-foot of installed green roof.[25] After qualitatively assessing the location of the other studies, the type of building being studied, and any other factors that may cause the value to differ from the case study roof, three levels of benefit value were selected for each benefit (low, medium, and high, medium being the most realistic scenario). Personal knowledge of university operations and missions, as well as interviews with Mason administrators, enabled the author to complete the list of benefits and costs.

The process of assigning value to each cost and benefit is presented below. Certain costs or benefits were eliminated from the final analysis as discussed in section **5.8.**

5.2. Market Benefits

The two main market benefits of a green roof are energy savings and extension of roof life.

[25] Incremental benefits and costs are defined as the difference between the value of implementing a particular policy and not implementing a particular policy. Assuming that "business as usual" is for Mason to install a standard built-up roof, incremental benefits would be the increase or decrease in benefits as a result of implementing a green roof.

5.2.1. *Energy Savings*

Energy savings is the value of the avoided kWh of electricity used to cool the building combined with the value of the avoided BTUs[26] of natural gas energy used to heat the building, as saved through insulation and plant evapotranspiration. The range of energy savings estimates among reviewed green roof studies (from a 2% loss of energy in wintertime in Pennsylvania to a 50% gain in summer in Ann Arbor) creates a potential difficulty in estimating this benefit. On top of this, not much data exists actually comparing pre and post-installation energy usage of buildings. This study compares the number of heating degree days, cooling degree days[27], and average annual rainfall between all study sites to adjust each energy estimate accordingly.

The local green roof consultant had the most conservative estimate of a 1-2% energy savings based on the fact that this building's roof has a concrete deck, which is a very good insulator. According to Acks (2006), savings can range from 1% to 20%, and a short building will have a greater energy savings per square foot than a tall building because the ratio of square feet of roof to square feet of interior space is higher. The proposed project only covers part of the SUB II roof, but it would cover the part of the building that is only one story, leading to the conclusion that the energy savings should be higher than for a tall building. Since only part of the building roof would be covered, 10% was selected as an appropriate middle ground from Acks' study. The Pennsylvania State University (Penn State) Center for Green Roof Research, the study site located

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[26] British Thermal Units (BTUs). BTUs are defined as the measurement of heat generated by burning any material.

[27] A cooling degree day is a cumulative measurement of the number of degrees above 78 F and a heating degree day is a cumulative measurement of the number of degrees below 65 F. http://www.ersys.com/usa/51/5126496/wtr_norm.htm

nearest to Mason's campus, estimates an energy loss of ~2% in winter and an energy gain of ~10% in summer for their roof. However, State College, PA, has many more heating degree days than the DC Metro Region's, and fewer cooling degree days. It is possible, therefore, that the same roof installed on Mason's campus would more greatly benefit the overall energy usage of the building over the course of the year because our greatest energy load is during the hot and humid summer, so an estimate of 8% overall was used from this study. Wong (2003) estimates a 14.5% energy savings on a green roof in Singapore, and Carter and Keeler (2008) estimate a 3.3% energy savings in a roof in Athens, GA – both places are much hotter and more humid than Mason's climate.

Because the local green roof consultant had extensive experience assessing energy benefits for regional projects, his two estimates were selected for the low (1%) and medium (2%) scenarios. From the fact that the average energy savings for all of the other studies was much higher than 2% - about 6.4% - it became evident that it was feasible for the energy savings to be higher. As such, the high scenario was estimated at a conservative 6.4%. Total energy costs to heat and cool the space in the SUB II building are \$1.25/ft^2 heating and cooling for an entire year.[28] Under energy saving scenarios from 1-6.4%, the roof would save between \$0.0125 and \$0.08 per square foot annually.

In addition to energy savings, increase in energy costs over time will increase the financial benefit of energy-saving projects. Since 2004, electricity costs for Mason per kWh have risen by about 40%. With impending cap-and-trade climate policy being developed in the United States, there is no way to tell how costs of a coal-driven energy

[28] Fiscal year 2007 data.

producer (like Mason's electricity provider, Dominion Electric) will increase, but the impact will most certainly be in an upward trend. The long-term benefits of the green roof are likely underestimated as a result. Costs for CO_2 mitigation, resulting from Mason's commitment to climate neutrality, are addressed within indirect benefits.

5.2.2. Extension of Roof Life

Extension of roof life is the value of the avoided cost of having to replace a standard roof more often than a green roof, which is measured in life years. There were found to be numerous opinions about how long a green roof could last, which made our cost analysis all the more challenging. Roof life of 20 years is expected for a standard built-up roof like the current roof. The most conservative estimates place the life of a green roof at double the life of a standard roof, or at about 40-50 years (Acks, 2005; Wong, 2003; Carter & Keeler, 2008). Other studies cite examples of roofs in Germany that had no significant maintenance conducted for 90 years (Porsche & Kohler, 2003). Hence, the sensitivity analysis included analyses of 40, 60, and 80-year roof life scenarios – 40 years being a bare minimum because warranties typically cover a 40-year roof life, and 80 years being an unlikely but possible scenario. Based on the cost of a standard roof of $54,180, the cost of the green roof of $90,300, a standard roof lifetime of 20 years, and a lost roof life of 10 years (since the roof would be replaced with half the warranted roof life remaining), and with no other benefits taken in to account, the green roof would have to last approximately 60 years without any major repairs for the cost to break even with the value of a standard roof.

5.3. Indirect Market Benefits

5.3.1. Stormwater Management

The value of stormwater management is the value of retaining and slowing the flow of stormwater off of the roof, measured in dollars per square foot. This is money that is saved through avoided infrastructure maintenance for sedimentation controls and infrastructure damage resulting from heavy rain events. George Mason University does not currently track spending specifically to operate and maintain storm water management structures on campus. However, dredging the two main storm water management structures (the Mason Pond and the Braddock Avenue weir) between 2006 and 2010 are estimated to cost between $300,000 and $400,000. This is not "typical," however; extremely rapid development on the Fairfax campus has added a much higher level of sedimentation burden to these structures than would occur on finished and landscaped land. [29]

Water management on campus will continue to be a concern as a result of two main factors:

1) Increase of impervious surfaces: Mason is continuing to expand for the next five years at a rapid pace (expected to build about 2 million additional square feet in the next 5 years). While Mason plans on restoring green space in currently impervious areas, the overall percentage of impervious surface will definitely rise unless the university makes a concerted effort to keep impervious surface to a steady-state. This will greatly increase the amount of stormwater runoff that must

[29] Interview with Mason's Assistant Director of Facilities Management, Ralph Lewis, 7/09.

be managed, and therefore increase the costs associated with said management, unless on-site stormwater management practices are rigorously pursued.

2) Extreme weather: Changing climate conditions including heavier and more frequent rain events will add to the costs of managing storm water runoff. As a recent example, two roads collapsed under the severe erosion conditions created by a 100-year rain event in spring semester 2009 which cost the university over $200,000 to repair. Without a concerted effort to begin retaining and percolating water on site, the university can expect to see more repair costs incurred as a result of severe storms.[30]

Previous research calculating the value of stormwater management resulting from their roof studies were based on the avoidance of stormwater management fees charged by local governments as a penalty for impervious building. However, the city of Fairfax, county of Fairfax, and the Commonwealth of Virginia do not charge such fees, so stormwater management costs were not used in the final calculation of benefit. Values from road repair and stormwater management on Mason's Fairfax campus were used to arrive at per-square-foot values of the cost to mitigate stormwater on Mason's campus. Combining the costs for maintenance and extreme events, a low value of $0.0023 per square foot, a medium value of $0.003, and a high value of $0.0044 per square foot per year were calculated.

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[30] According to the U.S. Global Change Research Program report titled *Global Climate Change Impacts in the United States*, the region will experience "more frequent and intense heavy downpours" and "more rainfall during heavy precipitation events." http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts

5.3.2. Reduction in CO_2 generation

In 2007, Mason's President committed the university to climate neutrality via his signature on the American College and University Presidents Climate Commitment (ACUPCC).[31] This commitment signifies Mason's understanding of their responsibility for greenhouse gas emissions contributing to climate change, and accepts responsibility for reducing that negative externality. The benefit of reducing CO_2 generation is the value of avoided mitigation costs through the purchase of carbon offsets or renewable energy credits. The savings resulting in a reduction of CO_2 are calculated as a result of the three potential levels of energy reduction: 1%, 2%, and 5%. However, prices for carbon offsets are extremely variable in today's market, depending on the source, the type, and the cost of the offset measure. For example, one vendor approaching Mason's Office of Sustainability about purchasing offsets presented an estimated cost of approximately $1.80 per metric ton (MT) of carbon dioxide equivalent (eCO_2)[32], but carbon offsets from myclimate Switzerland range in price from $33/MT to $99/MT eCO_2.[33] The median price in a recent listing from Ecobusinesslinks.com was about $15. Low scenario was calculated as $1.80, Medium as $15, and High as $99 for the short term. A recent report from the Department of Energy's Energy Information Administration (DOE EIA) was released calculating the effect of the Waxman-Markey bill on the future price of carbon emissions should it be passed. Those estimates were used for the longer-term scenarios between 2020 and 2030 (Low: $20, High: $93, Medium calculated as an average of Low

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[31] The full text of the ACUPCC can be found on www.presidentsclimatecommitment.org.

[32] eCO_2 is carbon dioxide equivalent. In order to offset emissions, all sources of climate-affecting emissions must be calculated as the same unit. Since carbon dioxide has the lowest per-unit impact on climate, it is used as the basis for most greenhouse gas inventories of total emissions.

[33] According Ecobusinesslinks.com Carbon Offset Survey, updated as of August 19, 2009. http://www.ecobusinesslinks.com/carbon_offset_wind_credits_carbon_reduction.htm

and High: $57), and for 2030 and beyond (Low: $41, High: $191, Medium calculated as an average of Low and High: $116). [34] The great range in prices resulted in a great range of potential benefits from carbon avoidance in the most conservative roof life scenario of 40 years: $0.01 to $1.02 per square foot.

An important issue to note is that it is possible to reduce emissions through cheaper methods, like reducing energy consumption or improving efficiency. So reducing CO_2 in other ways may actually be less costly. Mason would only need to acquire carbon credits after 2050, when it has committed to being climate neutral. However, markets may change drastically between now and then.

5.4. Non-Market Benefits

5.4.1. Reduction in air pollution

The benefit of reduction in air pollution is the value of human health improvement resulting from improvement of regional air quality. Financial values from various green roof studies range from $0.04 (Clark et al, 2007) to $1.43 (Acks, 2006) per ft^2 per year. For the 6020 square foot Mason green roof, the range of benefits would be from $240.80 to $8,608.60 annually. Over a 40-year lifespan, the roof would produce health benefits ranging from $9,632 to $344,344. These calculations do not include CO_2 as a pollutant (as recently classified), but include the benefits of reducing particulates and oxides of nitrogen.

Fairfax County has exceeded the maximum for EPA's National Ambient Air Quality Standards for ground-level ozone within an 8-hour period since at least 2001

[34] http://www.eia.doe.gov/oiaf/servicerpt/hr2454/execsummary.html

(Kumar, 2009). Ground-level ozone, in part, is caused by the interaction of oxides of nitrogen with sunlight. Nitrogen oxides are created for the most part in Fairfax County by mobile sources. Being a commuter university, Mason in no small part contributes to the ground-level ozone problems in Fairfax County. Nitrogen oxides are absorbed by plants. Adding plants to Fairfax is therefore an act of community stewardship, as they clean the local air and make it healthier for residents of the County.

5.4.2. Creating environmentally educated and aware students, faculty, and staff

The benefit of creating environmentally-educated students, faculty and staff is the value of an environmentally-aware community member, calculated based on their assumed reduction in energy consumption. Many schools report significant energy and water savings during residence hall energy competitions[35], between 3.9% and 56% by dorm. Oberlin found that post-competition, residents report that they have retained many of the practices they learned through the competition. Mason had a pilot energy competition between two small residence halls in the spring of 2008, and found that the energy savings for the winning residence hall was about 2.75%, and more money was spent on the competition than was saved on energy.

The green roof would be used not only to educate students on green roofs, but on various ways they could save energy in their lives on campus. For this calculation, we assumed that of Mason's full-time student count of about 23,000[36], about 10% of those

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[35] Energy competitions pit residents against each other to win prizes for reducing their energy consumption the most over a set period of time.
[36] George Mason University Office of Institutional Research and Reporting, 2008-2009 Factbook Quick Facts. http://irr.gmu.edu/factbooks/QuickFact200809_Final.pdf

students would circulate through the student activities space that will be established in the building renovation, or 2,300. Assuming the university would couple the green roof with the correct social marketing techniques to lead to permanent behavior change (McKenzie-Mohr, 2000; Mason Climate Change Communication Strategy, 2007), we assumed that some proportion of these students (low-medium-high scenarios of 5%, 10%, and 20%) would reduce their on-campus energy consumption, and greenhouse gas emissions, by about 10% per year. Each student at Mason emits an average of 5.1 MT eCO2 per year.[37] By using the same prices for carbon offsets that were used in the calculation of energy saving benefits, potential savings per square foot of green roof were between of \$0.18/ ft^2 at a low offset cost and 40-year roof life, and \$521.42/ ft^2 at the highest offset cost and an 80-year roof life.

5.5. Market Costs

5.5.1. Increased initial cost and replacement of roof installation (includes design)

Issues of *first cost*[38] greatly affect universities with limited resources. Although it may cost less to operate a building over time if, for instance, a green roof is installed, the initial cost of the roof is a limiting factor, sometimes being triple the cost of a standard roof.

The cost of increased initial cost and replacement is the value of the *added* up-front cost for designing and installing a green roof over a standard roof. A proposal for a green roof installation on the student union II building (SUB II) was initially developed

[37] 2007 George Mason University Greenhouse Gas Inventory: http://acupcc.aashe.org/upload/ghg/NDAwOC0yMDA3LWludmVudG9yeXJlcG9ydHMtR01VX0dIR19JbnZlbnRvcnlfUmVwb3J0XzIwMDdfMDkwNDA5X0ZJTkFMX05PQU5ORVgucGRm.dl

[38] Also known as up-front cost or capital cost.

by a local green roof consulting company[39] in late 2006 (see Appendix A), and the costs were updated in 2009. The local green roof consultant's estimate for this proposed green roof is approximately \$15 per square foot installed, which is incrementally \$6 greater than the standard built-up roof, at \$9 a square foot. This cost was calculated as a *marginal* cost (the difference between purchasing a green roof and a standard roof) over a 40-, 60-, and 80-year roof life scenario, subtracting the foregone value of the current warranted roof. The value of the roof just based on roof life was -\$13.50/ft^2 for a 40-year roof life (a negative NPV), \$1.50/ft^2 for a 60-year roof life, and \$16.50/ft^2 for an 80-year roof life. Essentially, if excluding all other costs and benefits from the calculation, installing a green roof would have the same incremental value as a standard roof at slightly less than 60 years.

5.5.2. Loss of life on current roof

The cost of the loss of life on the existing roof is the loss of warranted roof life on the existing roof should it be replaced immediately with a green roof. If a roof is not at the end of its life (i.e., the warranty has not yet expired) we need to consider this a loss of useful life. In our case, the roof was installed in the year 2000 and therefore would lose 10 years of its useful life, or about \$27,090. This amount was included in the calculation of the incremental value of the roof life, above.

5.5.3. Maintenance costs

Maintenance costs include the costs to replace dead plants, perform annual weeding/watering during the roof establishment period, and to treat for unwanted insect

[39] Greg Long from Capitol Greenroofs in Arlington, Virginia.

populations. Based on figures from two other authors (Acks, 2006; Porsche & Kohler, 2003), maintenance per square foot of green roof per year used a low scenario of \$0.31, medium of \$0.60, and high of \$1.10/ft^2. In the 60-year roof life scenario, it is worth noting that using the medium maintenance cost scenario created a negative incremental value for the green roof in the most conservative CBA, which did not include image and environmental awareness.

5.5.4. Cost for educational materials and marketing

The greatest benefit of installing a green roof results from the potential educational opportunities surrounding the roof, and the costs to leverage the green roof as a marketing tool for reducing energy consumption on campus would be minimal as compared to the total cost of the roof. The costs associated with this programming are the costs of providing signage, tours, and education. There are three types of spending on educational materials: permanent, semi-permanent, and ongoing. Permanent signage would include education about the purpose of the green roof and its ongoing benefits, and would need to be replaced every 10 years (cost of about \$500/year). Semi-permanent items would include reusable but removable banners used for annual recurring events, like Earth Week tours of the roof, and would be replaced about every 5 years (cost of about \$200/year)[40]. Ongoing expenses include time spent for sustainability office personnel to perform electronic education, print flyers, provide tours at special request, train patriot leaders and resident assistants, etc., and this would cost approximately

[40] Based on costs at Fast Signs in Fairfax, VA.

$1,000/year. [41] Altogether, these costs amount to approximately $0.28 per year per square foot of roof.

5.6. Indirect Market Costs

5.6.1. Cost to re-train maintenance personnel to maintain new technology

These are the costs incurred to train maintenance personnel on maintaining the new roof safely. This cost is typically included in cost of installation, and this is definitely the case for our proposed green roof installation.

5.7. Non-Market Costs

5.7.1. Potential negative reaction from parents, state legislators, and Virginia taxpayers not understanding why money is being spent on this versus other projects

This potential cost can be mitigated through proactive education and awareness campaigning, and preventing failure of the roof at all costs.

While university administrators were skeptical at first of installing a green roof on the Forestry Building at Penn State University, the unequivocal success of the installation (both in terms of aesthetics and functionality) alleviated those concerns and paved the way for further green roof usage on campus. However, it should be noted that a catastrophic failure can have just as strong an opposite effect, and this was the case with permeable asphalt paving on campus: poor installation and bad timing has created an aversion to using permeable asphalt on their campus, and they do not anticipate trying again any time soon.[42]

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[41] Based on experience of the author spending on other promotional materials.

[42] Interview with Dr Berghage from The Pennsylvania State University's Center for Green Roof Research, 6/26/09.

5.7.2. Benefits and Costs Summary

Summary tables of benefits and costs, by author, appear below. Several costs and benefits were eliminated for various reasons, which are detailed in section 5.3.8.

Table 2: Green Roof Case Study Benefit Summary

Market Benefits	Benefit Levels Chosen		Author(s)/Source(s)	Study Value of Benefit
Energy savings	Low	1% energy savings	Wong, 2003	14.50%
	Medium	2% energy savings	Acks, 2006	1-20%
	High	6.4% energy savings	Clark et al, 2007	50%
			Carter and Keeler, 2008	3.30%
			Mason Data	1-2%
Extension of roof life	Low	40 yr roof life	Porsche and Kohler, 2003	90 years
	Medium	60 yr roof life	Acks, 2006	20-60 years
	High	80 yr roof life	Clark et al, 2007	40 years
			Carter and Keeler, 2008	40 years
Indirect Market Benefits	**Benefit Levels Chosen**		**Author(s)/Source(s)**	**Study Value of Benefit**
Stormwater retention	Low	$0.0023/ ft2	Porsche and Kohler, 2003	$8.38/ft2
	Medium	$0.003/ ft2	Clark et al, 2007	$0.09/m2
	High	$0.0044/ ft2	Carter and Keeler, 2008	$0.004-0.007/ ft2
			Mason Data	$0.0023-0.0044/ ft2
Reduction in CO2 generation	Low: Today - 2019	$1.80/MT CO2	DOE EIA Report: "Market and Economic Impacts of H.R. 2454, the American Clean Energy and Security Act of 2009"	Ranges from a low cost per carbon offset of $20 in 2020 to a high cost of $191 in 2030
	Medium: Today - 2019	$2.75/MT CO2	Verus Carbon Neutral CCX	$2.75/ offset
	High: Today - 2019	$99/MT CO2	Myclimate Switzerland	$99/offset
	Low: 2020-2029	$20/MT CO2	Mason Proposal	$1.80/offset
	Medium: 2020-2029	$56.5/MT CO2		
	High: 2020-2029	$93/MT CO2		
	Low: 2030 onward	$41/MT CO2		
	Medium: 2030 onward	$116/MT CO2		
	High: 2030 onward	$191/MT CO2		
Non-Market Benefits	**Benefit Levels Chosen**		**Author(s)/Source(s)**	**Study Value of Benefit**
Reduction in air pollution	Low	$1.47/ ft2	Acks, 2006 (p. 50) - particulates only	$1.43/ ft2
	Medium	$1.53/ ft2	Clark et al, 2007 - NOx only	$0.4-0.16/ ft2
	High	$1.59/ ft2		
Creating environmentally educated and aware students, faculty, and staff	Low	5% of students exposed to the roof reduce energy consumption by 10%	University of Connecticut Eco-Madness Competition	Saved between 0% and 21.75% energy per dorm
	Medium	10% of students exposed to the roof reduce energy consumption by 10%	Texas A&M Energy Competition	Saved between 3.9% and 20.15% energy per dorm
	High	20% of students exposed to the roof reduce energy consumption by 10%	Oberlin University Dorm Energy Competition	Saved an average of 32% for all competing dorms

Table 3: Green Roof Case Study Cost Summary

Market Costs	Benefit Levels Chosen		Author(s)/Source(s)	Study Value of Cost
Increased initial cost of roof installation, including design		One value used, from proposal	Wong, 2003	$89.86/m2 or $27.38/ft2
			Acks, 2006	$12-24/ft2
			Carter and Keeler, 2008	$158.82/m2 or $48.41/ft2
			Mason Roof Proposal	$15/ft2
Loss of life on current roof		One value, included in installation costs	Mason Data	$27,090, or $4.50/ft2
Maintenance costs	Low	$1.10/ft2	Acks, 2006	$0.60 - $1.10/ft2 per year
	Medium	$0.60/ft2	Porsche and Kohler, 2003	$0.305/ ft2 per year
	High	$0.09/ft2		
Cost for educational materials and marketing		One value	Mason Sustainability Office	$0.28/ ft2 per year
Indirect Market Costs	**Benefit Levels Chosen**		**Author(s)/Source(s)**	**Study Value of Cost**
Cost to re-train maintenance personnel to maintain new technology appropriate maintenance of the green roof		Not applicable	None	$0
Non-market Costs	**Benefit Levels Chosen**		**Author(s)/Source(s)**	**Study Value of Cost**
Potential negative reaction from parents, state legislators, and Virginia taxpayers not understanding why money is being spent on this versus other projects		Not applicable	None	$0

5.8. Excluded costs and benefits

Image Enhancement

Image enhancement is measured as the dollar value of increasing demand for attending George Mason University. Students (and to a lesser extent their parents) are beginning to seek out schools that have made a commitment to greening their operations. In a 2009 Princeton Review survey, 68% of incoming freshmen surveyed said a school's environmental performance would be a factor in choosing where to go to school, and 26% said it would *very much* or *strongly* affect their decision on whether to attend.[43] For higher education, image enhancement has several aspects: educational quality and

[43] Princeton Review Green Rating Press Release: http://ir.princetonreview.com/releasedetail.cfm?ReleaseID=324924

innovation, quality of life on campus, and community goodwill, i.e. economic, social and environmental stewardship of the local community, otherwise known as "town-gown relations."

Much positive press is generated through innovative stewardship commitments that positively impact the communities local to universities. In the case of Penn State University, for example, their Center for Green Roof Research exemplifies the school's commitment to "going green" in several ways: 1) it recognizes the impact of increased stormwater management issues resulting from its' approximately 50% impermeable surfaces on both their own costs and costs of the surrounding community, 2) it tells the rest of the world that their commitment doesn't just impact their own community, but through research can positively impact decision making by private land owners or local jurisdictions, and 3) it distinguishes the university as unique, in that there are few universities in the United States studying green roofs to this depth of commitment.[44]

Ivy (2001) quotes Kotler and Fox (1995), saying: "…people form images of [higher education institutions (HEIs)] on limited and even inaccurate information, but that these images will affect the likelihood of people attending, recommending, donating, or joining the staff of HEIs." In addition, Ivy states that "an HEI image is not absolute, but relative to the images conveyed by other HEIs." While students would prefer to attend a school with a strong reputation for operational greening (as indicated by the Princeton Review survey), most students will make their final decision on the basis of educational program availability, quality, and cost. Because greening activities reduce the

[44] Interview with Dr Berghage from Penn State's Center for Green Roof Research, 6/26/09.

overall cost to operate a university, money can be spent on educational programs. It is in this way that greening can financially impact the institute of higher education.

Based on Mason's enrollment forecasts from 2010 through 2015[45], and on the stated value that students place on the "green-ness" of an institution according to the Princeton Review Hopes and Fears survey (that is, the 26% of those students who say it would *very much* or *strongly* impact their decision to attend), the green roof (as an indicator of the university's commitment to sustainability) could potentially increase enrollment at Mason by approximately 95 students per year (annualized over 6 years). Unfortunately, an increase in student enrollment does not have a positive impact on Mason's revenues. Currently, in-state students equate to an approximately $7000 loss to Mason's budget. Out-of-state students equate to approximately a $7000 gain, but only account for about 17% of the total student population in 2009. Thus, the total loss per square foot of roof resulting from an increase in enrollment is about $72.63. For the medium scenario, half of that amount was used, and for the high scenario, $0 was used, meaning that no additional students enrolled as a result of Mason's green reputation. This latter scenario is plausible, since there is no way to verify that the students' decision would actually change as a result of a school's green reputation.

An increase in students coupled with declining state general funding per student has made it necessary to repeatedly increase tuition rates to stay solvent. However, the

[45] Data from George Mason University's Campus Planning Department

quality of the incoming students has risen over time.[46] This is a result of an increase in reputation as Mason's research and education programs improve in quality and breadth.

This cost was initially categorized as an indirect market benefit, but was re-classified after discussions with the Mason Budget Office. However, this was done reluctantly. No quantitative studies were found showing that reputation correlates to increased grant funding or endowment size, but this is a well-known fact to higher education administrators.

Attracting students who are environmentally minded and aware begins to build a culture at the university that favors conservation as the social standard, rather than the exception. Over the long run, this leads to conservation behaviors by students, staff and faculty.

Increase in grant monies and donations

This benefit measures the potential value of increasing the ability of the university to capture research grants and/or donations with a green roof program. While most universities do not track their donations resulting from a particular green roof, grants are fairly easy to track. The issue with grants is that for the most part, green roofs are not funded by grants unless the university in question already has an existing green roof study program, or has a rigorous plan in place to study the green roof. Mason has neither. However, Mason does boast a strong focus on experiential (hands-on, or applied) learning, through its New Century College. In addition, Mason's Civil Engineering and Environmental Science and Policy Departments contain strong proponents for applied

[46] From 2003 to 2008, enrolled freshmen average GPA has gone from 3.32 to 3.48 and average SAT scores have gone from 1109 to 1121. George Mason University Total Budget 2009-2010, Executive Summary, page 23.

learning, which can be enhanced by access to a green roof. Therefore, faculty and students in these departments would be likely to apply for grants to support this learning opportunity.

Two university grant-funded green roof programs were examined in some detail: Penn State Center for Green Roof Research and University of Central Florida's Stormwater Management Academy. Their grants both supported construction of the green roof, and were specifically geared toward long-term study of green roof performance for approximately 5 years. Based on these two funded programs, this equates to a Medium scenario of $11 per square foot of built roof, and a High scenario of $48 per square foot of built roof. The Low scenario of $0 per square foot of installed green roof annually is very possible, because Mason does not have a green roof program. As with image enhancement, these figures are very large and highly uncertain. As compared with other per-square-foot benefits, it is on the order of 100 times larger.

One other potential source of rather sizable grant-related benefits comes from the federal Circular A-21 program, otherwise known as the indirect cost reimbursement program[47], which provides money to any university in receipt of federal research grants. Effectively, this enables the university to partially offset the building and operation of any lab that supports work being done on a federally-funded grant project. Unfortunately, this benefit is very difficult to track down and calculate, because federal funding of green roof study is more rare that regional funding, where green roofs directly impact

[47] For more information, visit PennState's "A Primer on Indirect Costs": http://www.research.psu.edu/osp/PSU/Proposal/indirect.htm, accessed 11/09.

watershed quality issues. For all the reasons above, grants were excluded from the final analysis.

Increase in students working in the "new green economy"

Much has been said about how to encourage learning in fields that will make the United States competitive in the global low-carbon market. It has been suggested that students who participate in service learning in their undergraduate years tend to select a service-oriented career upon graduation as a result of their experience (Astin et al, 2000). However, the same study shows that the single most important factor in the reception of the experience is the student's interest in the subject matter, which suggests that students who have a strong interest in green building methods would most highly benefit from the opportunity to study and potentially install a green roof on Mason's campuses. The production of students capable of serving in the new green economy will indirectly lead to improved image, and will also draw students interested in a hands-on experience to Mason, thereby increasing the number of applicants as well as enabling Mason to improve the quality of their students. However, because no studies were located that attempted to value the benefit of being prepared to serve the needs of the current economy, this benefit could not be quantified.

Food production

The food production benefit is the financial value of growing local vegetables atop buildings. The roof being assessed does not have the weight capacity to grow food, so this potential is not being considered. However, other roof space that does have the weight-bearing capacity should be considered for this purpose, as real estate to grow food at ground level, and security of food resources, would make rooftop farming appealing. Insects have less access to rooftop food, as well, making it less likely that the plants would need to be treated with insecticides. Acks (2006) estimated a benefit of approximately \$0.10/ft^2.

Aesthetic improvement

The benefit of aesthetic improvement is measured as the value of increasing visual access to green space. Aesthetic improvement implies no direct interaction with the green roof space. The addition of green space where there previously was not ready access to green space makes aesthetic improvements relevant in cityscapes and commercial buildings with no view of green space previously. Mason's campus, however, still retains a great deal of its trees, and from the adjacent space, a forested area is already visible. This benefit is recognized but not quantified by Porsche and Kohler (2003). Acks (2006) values aesthetic benefits using a range of willingness to pay values, from \$10-\$50 per person, but the source of the data is not cited.

Reduction in CO_2 generation – climate change mitigation global value

This benefit is the value of positive impact on global climate change through reduction of CO_2. Acks (2006) uses \$0.18/ft^2 based on large-scale implementation of green roofs at a city-wide level. This particular benefit is not applicable, because our scale is so small and climate modeling is still uncertain for the benefits of CO_2 uptake of specific flora. As a result of this fact, neither Mason nor the region can capitalize on the CO_2 uptake of the plants as a result of either selling these offsets or claiming them as offsets for Mason's own emissions. However, if calculated using the large-scale number above, we would arrive at a societal benefit of $1083.60/yr, or $43,344 over a conservative 40-year lifespan of the roof. In the future, when typical extensive green roof flora is tested for CO_2 uptake, this benefit may accrue.

Reduction of water pollution in local waterways

This benefit is the financial value of regional water quality improvement. The reduction of pollution in local waterways is a benefit to local ecosystems. However, because Mason cannot capitalize on this benefit either through mitigation reduction, this benefit was excluded. If there were state incentives to reduce pollution in local waterways, this benefit would apply to all stormwater management practices.

Reduction in noise pollution both inside and outside of building

The reduction of noise benefit is the value of the reduction in noise pollution within the building as a result of the green roof insulative properties. The value of noise reduction has been cited by several authors (Porsche and Kohler, 2003; Barreiro et al, 2005; Acks, 2006; Peck et al, 1999) but only one conducted a contingent valuation study on household willingness to pay for that noise reduction. Barreiro, et al, calculated that households were willing to pay about 4 euros per decibel (dB), or between 26 and 29 euros per year per residential household, equating to about $5.69 in 2009 dollars ($5.22 in 2005 dollars). Acks (2006) cited an approximate 3 dB soundproofing benefit, which was used to quantify an increase in property value (or about $15.66 per year based on Barreiro's estimate). Peck et al (1999) cite that a 5" substrate can provide up to 40 dB of relief from noise (valued at about $56.89 as per Barreiro). Mason's campus does not suffer from any appreciable noise pollution. The benefits afforded by this roof in this way are believed to be negligible.

Habitat creation/increase of biodiversity

The benefit of habitat creation is the value of creation of new habitat for local species of insect and birds. Green roofs can create valuable habitat for invertebrates and birds that cannot be replicated at ground level as a result of high traffic or changes in ecosystems resulting from landscaping practices. Multiple studies in Europe have confirmed the desire of species to utilize green roofs for breeding. For example, on a study about several green and brown roofs in England, Kadas (2006) found that "Almost 10% of the whole UK national and almost 20% of the Greater London spider fauna was recorded from these four green and six biodiverse roof sites." He concludes that "biodiverse roofs can be designed to replace conditions of specific habitat types at ground level." Upon closer inspection, Virginia only contains a handful of insects and birds identified as threatened or endangered. Of those, there are none that are likely to reside in northern Virginia.

While there are few ground locations safe enough for ground-nesting birds on Mason's campus without being disturbed, a roof location is not the most suitable location for young anyway, where there is no access to water for chicks. Baumann (2006) conducted a multi-year study focused on the breeding success of ground-nesting birds on five green roof sites in Switzerland, and although breeding was successful, the chicks did not survive. The author attributes this to predation and to a potential lack of access to food and water.

While only one of the green roof studies used as a data source mentioned habitat creation (Porsche and Kohler, 2003), this author believes there is a value of habitat that is simply too difficult to quantify within the scope of this study. The conclusion on this particular benefit is that in some cases, where there are local resident threatened or endangered species that are particular to the habitat of a green roof, unless specific attention is paid to creating a suitable habitat through recreation of ecosystems, the value of a green roof is negligible.

Community space creation

The benefit of community space creation is the social value of creating community space where little or none existed. The scheduled renovation to occur in the SUB II building in 2010 will create 12 new offices with windows overlooking the proposed green roof space. It will also create new student space that is to be used for student programming, governance, and Greek life. Multiple "work rooms" will also be adjacent to the roof terrace (intended to be also renovated and used as exterior space.) Green space is more relaxing than hardscape, and adjacent green space stays cooler as a result of the plant material. Effectively, this creates new outdoor real estate that was not previously usable. However, because there are numerous exterior community green space opportunities, we believe there to be no appreciable financial value to this addition of green space.

Studies have also shown that people on campuses would spend more time outside during their breaks if there were more green space available to them.[48] At Penn State University, the Forest Resources Building has a deck that is frequented by both tour groups and building occupants; feedback has been exceptionally positive although space cannot really be comfortably used in summer because of the direct sunlight.[49]There is no question that this space improves the quality of life on campus, but because there are "substitutes" in other locations on campus, this benefit was excluded. It does warrant further research, however.

Enhancement of health and well-being

The benefit of enhancement of health and well-being is the value of providing access to green space resulting in improved work and academic performance. Numerous studies have shown a correlation between exposure to the natural world and health and productivity. The Fairfax campus of George Mason University has always been adored for its unique quality of feeling like a forest campus. In recent years, however, the desire of the administration to grow as a well-known research institution has overshadowed the desire to retain this forested quality. Still, compared to other over-developed suburban land, this campus still retains a great deal of natural spaces. Not only do most (if not all) windows on campus overlook trees and natural areas, but access to these natural areas is a short walk. As such, the great benefits of interaction with nature that can be provided by a

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[48] Faul, A. K., "Increasing Interactions with Nature: A Survey of Expectations on a University Campus," Urban Habitats, Vol. 5, No. 1, May 2008. http://www.urbanhabitats.org/v05n01/university_full.html
[49] Interview with Dr Berghage from Penn State's Center for Green Roof Research, 6/26/09.

green roof will not be as pronounced at Mason as they might in a city, where a natural area may be miles away.

Potential roof failure due to poor installation or lack of education

This cost is the loss resulting from having to re-install the green roof and/or repairs on interior space as a result of roof failure. There is not likely to be additional incremental cost for roof replacement, as all reputable green roof installers now offer a roof warranty for the life of the roof, usually 40 years. More often than not, it is not the roof as originally installed that fails, but the roof will fail when people intervene to either maintain or study the roof. This is why education and training is critical after the roof is installed. This additional training is listed in indirect market costs, and is usually included in the price of the installation of the roof. This of course does not preclude the possibility for accidents to occur.

Opportunity cost

There are no plans to use the case study roof for anything other than this application – other applications would require further strengthening of the load capacity of the roof.

5.9. Cost Benefit Analysis – Methodological Approach

5.9.1. Approach

With six variables with three or more levels each, calculating every combination would have required over 1000 unique calculations. There would be no additional value to performing all of those calculations, because of the uncertainty of the source data. The goal of conducting a CBA is to generate timely actionable information for decision makers. These ranges provide adequate and timely information. If all variables had a simple three-level benefit, only three scenarios would have been calculated, for the Low, Medium, and High. However, the financial value of two variables – CO_2 mitigation benefit and environmental awareness – were contingent on the levels set for other variables. CO_2 avoided is directly impacted by the level of energy saved. The value of carbon offsets changes over time, as well, based on several estimates. The value of environmental awareness translates to reduced emissions per student, which can be calculated based on the expected cost of emissions offsets. Because emissions offset prices impact the value of not only offset cost, but environmental awareness value, a medium value for emissions price was selected for more of the scenarios than a low or high value. This was done to prevent a "multiplier effect" when changing the value of environmental awareness from low to high.

Table 4: Summary of Variable Values by Scenario

Scenario Summary*			
	Level of Most Variables, Except:	Emissions price	Environmental awareness
Scenario 1	Low	Low	Low
	Medium	Low	Low
	High	Low	Low
Scenario 2	Low	Medium	Low
	Medium	Medium	Low
	High	Medium	Low
Scenario 3	Low	Medium	Medium
	Medium	Medium	Medium
	High	Medium	Medium
Scenario 4	Low	Medium	High
	Medium	Medium	High
	High	Medium	High
Scenario 5	Low	High	High
	Medium	High	High
	High	High	High
	Key:		
	Low= Lowest Possible Value		
	Medium = Likely Value		
	High = Highest Value - Very Optimistic		

Table 4 shows a summary of the benefit and cost levels used for each scenario. The dollar value of each level in Table 4 can be found in Tables 2 and 3.

5.9.2. Discount rates and inflation

Three discount rates were evaluated: 0%, 3.5%, and 4.35%. These rates were selected because the benefits accruing to the university are immediate and ongoing, because the project may be funded by maintenance budgets (effectively cash, at 0% discount), and because the university often sells bonds to fund construction projects (3.5% for 10 years and 4.35% for 20 years). In the final cost benefit analyses, the rate resulting in the most conservative benefit was used for comparing all scenarios (4.35%). The differences between a 0% discount rate and a 4.35% discount rate produced a maximum difference in value of $26.90 for the High benefit 80-year roof life scenario (only a 4% difference).

While inflation usually should be taken in to consideration, because its existence makes future dollars worth less than current dollars, this study will not take inflation rates in to account for two reasons. First, the nature of using benefit transfer by its nature injects uncertainty in to valuation. Second, the cost of the green roof materials is likely to go down over time as the technology becomes more commonly installed. Therefore, any impact of inflation on the analysis should be insignificant, even over many years.

5.9.3. Assumptions

Several of the costs and benefits assessed have great potential variability. Some variability is not predictable, and therefore assumptions had to be made about their value.

1) Costs for green roofs will stay the same as they are today. This is not likely to be the case, as market penetration in the United States, along with the improved reputation of proven technology, causes installed prices per square foot to decline. However, there is no way to tell what defining moments will create a steep growth in this green building method, so for this analysis we assume that installation costs will stay the same over time. *This is likely to have the effect of understating the value of installing a green roof over a long time horizon.*

2) Mason will eventually need to purchase renewable energy certificates (RECs) or carbon offsets to meet its goal of climate neutrality. One of the largest potential areas of benefits is in the reduction of energy usage leading to the reduction in CO_2 emissions. As a signatory of the ACUPCC, Mason has committed to pursue climate neutrality. In spite of the university's best efforts to reduce consumption and to produce green energy, it is most likely that the university will need to buy carbon offsets for some portion of its emissions. It is predicted that the costs of emissions offsets on the open market will continue to rise over time as a result of federal policy implementation regulating the emissions of greenhouse gases. *This has the effect of potentially greatly inflating the value of the green roof installation, especially if the university's administration decides to make it a policy* ***not*** *to acquire offsets at all.*

3) Any installation of a green roof will be accompanied by educational signage and programming, thereby increasing the awareness of any community members exposed to the roof space. The costs associated with promoting the green roof space are minimal in a university environment, as the community is fairly insular and there are dozens of media with which to reach audiences. We must therefore assume that exposure to the green roof and the messages about how it saves the university money and climate emissions will have some positive impact on the behavior of the users of the space, even if minimal. *This cost is therefore included as a single-value cost for all scenarios.*

6. Results

Table 5 provides a summary the cross section of potential roof life for three different discount rates and for each of the three levels of costs and benefits for each scenario as described in section 5.9. The results point to several specific things for decision makers to keep in mind when assessing and then trying to capture all the benefits of a sustainability project like this green roof. Each is discussed below.

Table 5: Cost Benefit Analysis Summary – Values All Per Square Foot of Installed Green Roof

Cost Benefit Analysis Summary									
	40 years			**60 years**			**80 years**		
	Scenario 1								
Discount Rate (*)	Low	Medium	High	Low	Medium	High	Low	Medium	High
0%	$11.73	$45.67	$91.13	$21.74	$81.79	$154.49	$50.82	$96.84	$147.37
3.50%	($6.08)	$11.41	$37.81	($1.93)	$21.31	$53.68	$1.39	$16.76	$33.62
4.35%	($7.72)	$7.48	$31.13	($4.55)	$14.72	$42.55	$1.43	$10.20	$24.21
	Scenario 2								
	Low	Medium	High	Low	Medium	High	Low	Medium	High
0%	$22.70	$45.80	$71.31	$47.33	$82.03	$120.40	$98.35	$144.66	$195.95
3.50%	($0.85)	$11.47	$25.03	$7.00	$21.38	$37.26	$12.73	$28.18	$45.23
4.35%	$2.84	$7.53	$19.45	$9.48	$14.77	$28.25	$9.97	$18.80	$32.96
	Scenario 3								
	Low	Medium	High	Low	Medium	High	Low	Medium	High
0%	$39.77	$45.80	$88.39	$87.00	$82.03	$160.07	$171.93	$218.24	$269.53
3.50%	$7.35	$19.66	$33.22	$20.92	$35.30	$51.18	$30.36	$45.81	$62.86
4.35%	$9.76	$14.45	$26.38	$20.55	$25.84	$39.32	$23.28	$32.11	$46.27
	Scenario 4								
	Low	Medium	High	Low	Medium	High	Low	Medium	High
0%	$73.92	$97.03	$88.39	$166.36	$201.06	$160.07	$319.09	$365.40	$416.69
3.50%	$23.73	$36.04	$33.22	$48.75	$63.13	$51.18	$65.63	$81.08	$98.13
4.35%	$17.46	$28.30	$26.38	$35.77	$47.99	$39.32	$49.89	$58.72	$72.88
	Scenario 5								
	Low	Medium	High	Low	Medium	High	Low	Medium	High
0%	$154.91	$178.19	$204.14	$305.81	$340.78	$379.82	$546.24	$592.92	$645.11
3.50%	$75.54	$87.95	$101.75	$115.35	$129.85	$146.01	$141.88	$157.45	$174.79
4.35%	$64.72	$75.64	$87.79	$93.78	$106.09	$119.81	$113.65	$122.58	$136.99
* Discount Rates are:	0%: funded with cash			3.5%: 10-year bond rate			4.35%: 20-year bond rate		

Discount rates matter: If roof is purchased using cash (at a 0% discount rate), its value is positive at all Low variable settings. Depending on what method of funding is used, the value of the roof will be diminished. For example, if the roof was purchased using a 20-year 4.35% bond, in scenario 2 the roof's value will be only be between 10% and 27% of its value if paid for using cash. This leads to the conclusion that paying for projects like this in cash produces far more long-term value than if funded using other methods. Green roofs installed on new buildings are likely to be funded by bonds (as is the building), but roof replacements are funded by maintenance budgets, which is basically cash. In the case of the case study roof, because it is a roof replacement, it would most likely be funded by the maintenance budget. Regardless, generally speaking, it is advisable for these projects to be funded through maintenance budgets or through donations or interest-free loans, where possible, to reap the greatest benefits from the project.

Cost-benefit analysis using only market values is not adequate when assessing the value of sustainability projects: As shown in Table 6 below, when ONLY market benefits and costs are compared, all values returned are negative, regardless of discount rate used. This shows the inadequacy of using only market values in CBA to correctly value sustainability projects.

Table 6: Results from Traditional CBA Method

Market Benefits and Costs ONLY										
		40 years				60 years				80 years
Discount Rate (*)	Low	Medium	High		Low	Medium	High		Low	Medium	High
0%	($53.30)	($32.80)	($10.20)		($80.69)	($49.94)	($16.04)		($93.09)	($52.09)	($6.89)
3.50%	($40.49)	($29.55)	($17.48)		($43.65)	($30.87)	($16.77)		($44.31)	($30.60)	($15.49)
4.35%	($37.93)	($28.29)	($17.67)		($39.75)	($28.89)	($16.91)		($40.07)	($28.68)	($16.12)
* Discount Rates are:	0%: funded with cash				3.5%: 10-year bond rate				4.35%: 20-year bond rate		

Variables with the highest potential impact on roof value are also the most uncertain: When the discount rate is kept at 0% and the other variables kept at Low settings, the largest change in roof value occurs when changing the level of the emissions price from Low to Medium (an increase of between 93% and 118%) and Medium to High (an increase of between 71% and 110%). A change in awareness levels also increase the roof value significantly between Low and Medium (an increase of between 75% and 86%) and Medium and High (an increase of between 86% and 91%). See Table 7 for a summary. However, these variables are also the ones with the greatest uncertainty. In addition, the air pollution benefits are very high, but accrue to many other local community members outside of the purview of Mason's budget. As evidenced by the relative high value of these indirect market and non-market benefits, decision makers

Table 7: Change in Roof Value Resulting from Emissions Cost and Awareness

Positive Roof Value Change Resulting from Emissions Cost and Awareness					
	Emissions Cost Change			Awareness Level Change	
Roof life	Low to Medium	Medium to High		Low to Medium	Medium to High
40 years	93%	110%		75%	86%
60 years	118%	84%		84%	91%
80 years	94%	71%		75%	86%

must make investments in to making as many Mason community members aware of the project as possible, and ensuring it becomes part of a broader climate and sustainability awareness campaign.

Roof life is a significant factor in roof value: The value of the roof is significantly increased as roof life goes from 40 years to 80 years. For example, the value of the roof if its life is 80 years is approximately 333% higher than its value at 40 years using the same variable levels. The longer the roof lives, the longer its annual benefits can accrue, as well. It is therefore advisable for decision makers to do everything in their power to ensure the roof's longevity if and when the decision is made to install one, through training, signage, and making a reasonable up-front investment in an installer with a strong portfolio of credentials.

7. Discussion: CBA and the Alleviation of Information Asymmetry

As discussed in section 4, internal information asymmetries prevent university decision makers from answering some vital questions that enable them to identify and assess the indirect and non-market benefits associated with sustainability projects. In some respects, it is simple to assign responsibility to particular stakeholder groups for owning and working through each kind of information asymmetry. For example, alleviating technical information asymmetry should involve facilities managers, shop technicians, and code review boards. Economic information asymmetry is best overcome by budget decision-makers and financiers. Other forms of IA are cross-functional, and should be addressed at the highest level possible within the institution.

The process of constructing a cost benefit analysis can serve as a platform for building competency in

Table 8: Active Communications and Process Management are Keys to More Actionable CBAs

Cost Benefit Analysis and Active Communications Can Enable Decision Makers to Answer Vital Questions to Accurately Assess a Project's Total Value	
Barrier Type	*Question*
Conceptual Barriers	What is a green roof?
	What are the benefits for me or my department to understand and support a green roof?
Organizational Barriers	Does the green roof project support our mission?
	Can having the use of a green roof somehow increase the prestige of my department?
	Who owns the green roof's success or failure?
	Is someone already doing it at the university?
Knowledge Transfer Barriers	Will this green roof allow us to accomplish our goals?
	Do we even agree that a problem exists that the green roof can help solve?
	If so, do we agree what the problem is?
Technical Barriers	Can we even do it? Is a green roof feasible?
	If so, is it safe?
	How common is a green roof? Who else has done it successfully?
Economic Barriers	Can we meet our goals more cheaply?
	What are the true lifecycle costs of the green roof?

interdisciplinary projects and helping to reduce barriers to communication of all kinds in the university. The CBA can also be used to create a common language to support university-wide sustainability initiatives among stakeholder groups that infrequently have positive communication experiences.

For example, during the data collection process, the author had a chance to interact with all of the staff and faculty who would be impacted by the installation of a green roof, otherwise known as stakeholders. The experience with these conversations was diverse and enlightening. Some stakeholders were intrigued by the possibility of being able to quantify the non-market benefits of sustainability projects like a green roof. Some were confused about why they were being asked for a meeting, when they did not believe their input would ever have an impact on the final decision. In most, however, the light of recognition and interest shone through their initial suspicion and skepticism. Several of them contacted the author to inquire about the progress of this analysis, and others merely offered – un-prompted! – creative suggestions for how to make a green roof "work" at Mason. While there are no faculty members currently conducting research on green roofs at Mason, many were interested in integrating such a project in to their courses as experiential labs, showing their willingness to branch out into new areas when presented with a new teaching tool like this one. It became obvious that the process of data collection served to overcome *conceptual* barriers with the people who were engaged in the process.

Organizational issues are more challenging. A CBA process cannot solve a lack of understanding among university functions on its own. However, coupled with a cross-functional project review board (like Mason's Executive Steering Committee for Sustainability), a CBA provides the platform for discussion about how these projects impact the various functional areas like student life, operations, and academics. Through the conduct of the CBA, the sustainability office gains visibility and credibility with decision makers in other departments. This interaction educates other departments on ways these projects benefit their own departments, allowing them to further evolve their interdisciplinary sustainability strategies to incorporate several departments from the outset.

Knowledge transfer issues may be the only area where CBA cannot offer direct support, except that the CBA uses the common language of financial value to discuss sustainability. The great diversity of thought in a university is one of the sources of its uniqueness, as well as one of the downfalls in its ability to communicate across functions. Carlile (2002) describes this as a "knowledge boundary," creating a barrier to cross-functional problem solving. As described by Star (referenced in Carlile, 2002) in 1989, a "boundary object" can assist in overcoming knowledge barriers across functions. In our case, the CBA functions as the "boundary object" around which a common understanding of the problem or project can be defined by a cross-functional group. Ideally, facilitators without a vested interest in particular outcomes should be used to alleviate issues of conceptual and knowledge transfer issues.

As a CBA is conducted, *technical* limitations of the project must be discussed with the facilities and operations departments. Without prior feasibility assessment, financial valuation is useless. For example, if an existing roof *cannot* be reinforced with new structural components to support a green roof, that fact may make any further analysis moot. Through the process of including the appropriate personnel in the project review, these staff will learn about new technologies. However, the caveat to this is that the leadership of facilities must be supportive of encouraging personnel to spend time learning new technologies and best practices at other universities. Incentives can be used for this purpose.

Economic causes for information asymmetry are easily overcome if departments can be convinced that projects will financially benefit their departments and their mission. A CBA can provide the platform for discussion, and the justification for how a sustainability project builds value.

While the process of working through a cost benefit analysis *can* provide some alleviation to the five causes of information asymmetry, the construction of a CBA is limited in its ability to do so by the processes and interactions *surrounding* the construction of the CBA. By developing a standardized process which accompanies the conduct of project CBAs, e.g. an environmental management system, project recommendations will be systematically collected, reviewed, justified, and documented, building the institution's capabilities in the pragmatic evaluation of sustainability projects. This ultimately reduces the opportunity for failure, and successes will build upon other successes to move the university toward sustainability in a more systematic manner.

In combination with the CBA, information asymmetry can be addressed by systematic, inclusive, and persistent communication across all stakeholder communities. While some understanding always exists across the campus population, it is critical to engage the greatest diversity of people in gaining a basic understanding through social and academic interactions (Franz-Balsen & Heinrichs, 2007). Typically, a communication strategy will be constructed by a formal sustainability office, as this office is the information portal for disseminating information about sustainability across the university. The process of establishing the appropriate foundation for conducting a CBA, and for conducting the CBA, can be found in Appendix D. Table 8 provides a summary of the questions that will be answered about our case study green roof by combining the process of CBA and systematic processes and communications.

7.1. A word about the value of reputation in higher education

The exclusion of image enhancement and grants from the CBA was necessitated by two realizations: their high level of uncertainty and large relative size. This shows the importance of grants and research in making a project like this one financially feasible. The negative value for image enhancement is somewhat misleading, however. Although money appears to be "lost" per student, "the overwhelming majority of colleges and universities set price below the average cost of producing education for a single student, and a given school's ability to maintain or increase this subsidy hinges upon its access to non-tuition financing of all forms." (Cunningham & Cochi-Ficano, 2002)

Reputation is the capital of higher education. Instead of being profit-maximizing institutions, universities are "prestige maximizers" (Bowen, 1981). Cunningham and

Cochi-Ficano (2002) remind the reader that “current budgetary and admissions practices critically affect the long-term financial success of colleges and universities in a very dynamic context that renders standard static marginal cost and benefit analyses inappropriate.” Meaning that a dollar invested today leads to future returns, in this case as improved long-term reputation. A higher quality of reputation leads to a higher quality of faculty and students. This quality leads to greater research grant potential. Therefore, the cost of providing education and support for a high-quality student in itself should not deter universities from pursuing students. Rather, as the quality of incoming student goes up, tuition may follow suit, but the greatest reward is in the ability to capture research grants. Research grants not only provide the institution with funds to support installations of projects like a green roof, but they also lead to improved reputation, which leads to the ability to be more selective in student and faculty recruitment. This, in turn, feeds the reputation of the university, and the cycle continues. Appendix C provides an overview of Mason’s recent image enhancement wins and challenges a green roof may help ovecome.

7.2. Challenges with green roof valuation

Studies on green roof valuation (in general, not specific to university campuses) have shown there to be a great range of costs and benefits associated with green roofs versus standard roofs, when a range of benefits accruing to private and public decision makers is taken into consideration (Porsche & Kohler, 2003; Wong, 2003; Acks, 2005; Clark, 2007; Carter & Keeler, 2008). Some of the reasons for this phenomenon are:

1) The goals of the study are unique: researchers may have been funded by a city to provide policy decision making support around green roof policy (Acks, 2005, performed a study for the City of New York; Banting et al, 2005, performed a study for the City of Toronto); completion of dissertation (Clark et al, 2007)
2) Every study relates to unique situations, making comparison very challenging, including the use of different types of green roofs (intensive versus extensive) with differing components and media; different roof structures and assumptions; different geographical regions with differing abiotic conditions; and different local ordinances (and tax benefits or grants), local environmental challenges, and public opinion.
3) Each study has built upon previous studies: newer studies tend to have more benefits and costs taken into consideration
4) Some studies take lifecycle costs into consideration and some do not. For example, if including additional structural requirements required to support an intensive green roof (otherwise known as a roof garden, most often including trees and shrubs and intended for use by the community), initial costs would most certainly be much greater.

7.3. Challenges with valuing carbon offsets

The market and future of carbon offsets is very much in flux. Depending on legislation in the United States and elsewhere, the cost of offsets may rise exponentially, or may stay fairly flat. In addition, although Mason's goal of climate neutrality will be difficult to meet without offsets, it is unclear at what time the university will decide to purchase them. Offsets may be seen as a short-term way to meet these goals, but ultimately, the university does not directly benefit from this kind of investment, where the ongoing benefits of investing in, for example, the construction of a source of renewable energy may be more cost effective. Therefore, the inclusion of carbon offsets in this analysis is highly questionable until a public commitment is made by the university either way.

7.4. Areas for future research

Further study on the financial valuation of image enhancement in higher education would greatly improve the benefit profile of any sustainability projects being attempted. A consistent, nation-wide model for the valuation of green roofs, perhaps through Green Roofs for Healthy Cities, is critical to encouraging the adoption of green roofs in the United States in general.

Although many benefits and costs were excluded from the analysis, most of them were excluded because they did not apply to this particular green roof. However, some benefits have not yet been adequately assessed in relation to green roofs. Aesthetic value of a green roof, for example, could be greatly aided by more primary research using survey methods. The value of experiential learning provided through projects that can be integrated with curricula is an area also under-represented in the literature. Valuing noise reduction in relation to effectiveness of education and tying that to green roof noise-reduction benefits has also not been studied.

8. Conclusions

This study illustrated the fact that cost benefit analysis, when using only market values for costs and benefits, can be insufficient at enabling the accurate assessment of projects that have indirect and non-market benefits, like sustainability projects. While the analysis showed that adding in methods of social and environmental cost benefit analysis alone would be an improvement on the current lack of systematic assessment of sustainability projects, this process can only be used to overcome information asymmetries resulting in misallocations of funding when used as a "boundary object," allowing cross-functional teams to define the project and problem in a common language. However, the tool itself must be combined with standardized decision making processes and systematic communications in order to activate the significant latent interest in these kinds of innovative teaching and research tools.

In the end, it is important to remember the core mission of higher education: To produce educated adults who are prepared to address the issues confronting modern society. To reiterate the words of Anthony Cortese (2003): "Higher education institutions bear a profound, moral responsibility to increase the awareness, knowledge, skills, and values needed to create a just and sustainable future." By seeking out opportunities to integrate sustainability into research and curricula, universities may be able to capitalize on an opportunity to meet their core mission.

Appendix A: Overview of Green Roofs and of the Proposed Green Roof Case Study

Green roof overview

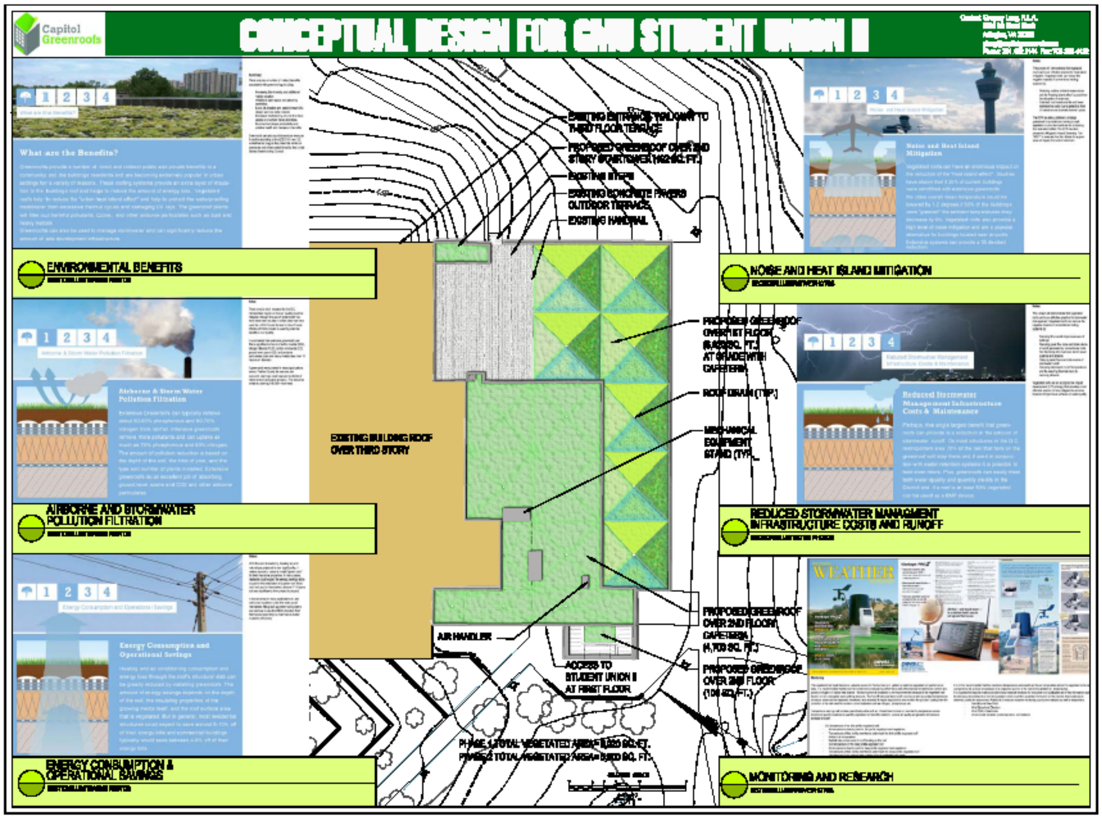
Simply defined, a green roof is a roof that has been planted with vegetation. Green roofs typically consist of a waterproofing membrane to protect against leaks, a water retention and drainage mat, a root barrier, insulation (if not included below the roof deck) and a layer of soil medium and vegetation.

There are two types of modern green roofs. *Extensive roofs* or low-profile systems are typically installed for energy conservation and water retention values, and the vegetation best suited to those purposes is generally not meant for frequent foot traffic. Instead, plants are chosen for their functional value, and the soil medium is typically 4 inches or less in depth. Extensive roofs are low maintenance after their initial establishment period of about 12 months. *Intensive roofs*, also called roof gardens, serve a more people-oriented purpose, creating meditative or social space in a natural setting. Intensive roofs may contain full-size trees, waterfalls or ponds, or even vegetable gardens, providing the ability to grow food in urban areas. Load requirements for intensive roofs are therefore much more significant and require irrigation and maintenance.

Green roof case study overview

A green roof proposal was constructed by Greg Long of Capitol Greenroofs in Arlington, Virginia. The original estimate was completed in 2006, and an updated estimate was provided in 2009. The green roof was to be an extensive green roof consisting of approximately 6,020 square feet of installed roof on the Student Union II Building on the Fairfax Campus of George Mason University. The roof was to be installed over a built-up bituminous roof over a concrete deck with 10 years remaining on its warranty.

Appendix A (continued): Green roof conceptual design



Appendix B: Analysis of Institutional Environment Supporting Green Roofs in the Washington, D.C. Region

An institutional environment is defined as "a composite of constituents within the firm's external social, political, and economic environments." As such, an organization is "bound by social influences, embodied in rules, laws, industry standards, best established practices, conventional wisdom, market leadership, and cognitive biases." (Hoffman, 2001) There are several aspects of a university's institutional environmental that favor the choice of installing green roofs: green roof penetration in the same geographical region, especially among institutions of higher education; local government legislation around green buildings and support of green roofs; and regional environmental issues that can be alleviated with green roofs.

In the United States, the numbers of roofs with gardens atop them are growing rapidly as cities begin to provide financial incentives and local mandates for favoring the installation of a green roof over standard roofing materials. In the Metro D.C. region, for instance, where green building legislation has begun to proliferate (Stewart, 2006), green roofs have started taking hold. The table above, produced from the International Greenroof Projects Database [50], shows the installed base of green roofs in the EPA's Mid-Atlantic (Region 3) states (International Greenroof Projects Database). Virginia leads the pack in registered total square footage of installed green roofs (884,089 ft^2), but there is only 1 project registered at a Virginia higher educational institution.[51,52] In Maryland and D.C., the story in somewhat different. Both Washington, D.C., and Maryland have incentive programs in place[53] for government institutions to install green roofs (see how Maryland and D.C. lead the pack in terms of number of registered projects). In fact, the state of

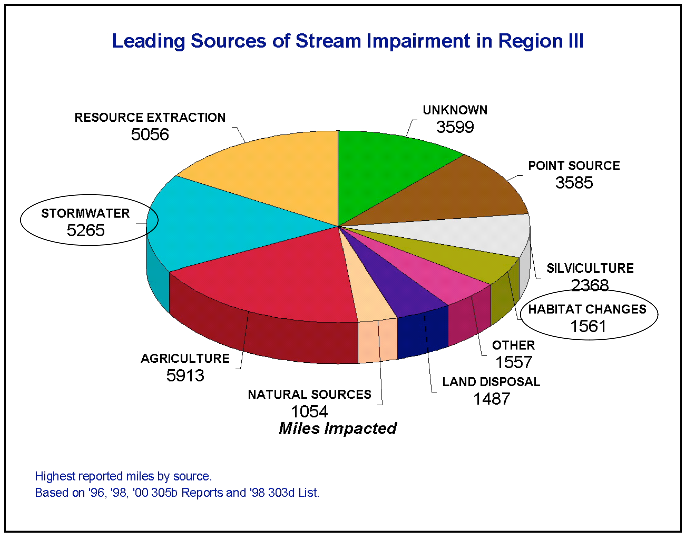
EPA Region 3: Mid-Atlantic States Installed and Planned Base of Green Roofs

State	# Projects in Colleges and Universities	# of Projects	Total Square Feet
Virginia	1	40	884,089 ft^2
Maryland	4	63	679,038 ft^2
Pennsylvania	8	43	474,945 ft^2
Washington, D.C.	3	46	324,791 ft^2
Delaware	0	3	30,970 ft^2

[50] The database only contains submitted projects – there may be significant projects not represented in these numbers.
[51] There are two exceptions: James Madison University, in Harrisonburg, VA has a green roof, but the project has been fraught with problems as a result of poor installation; Longwood University, a state school of only 3,700, has a green roof on their parking garage, but is not a competitor of Mason's. http://www.longwood.edu/greencampus/areas/greenbuildings/gbparking.html
[52] However, a few projects do not appear in the green roof database: Seitz Hall and Life Sciences Building at Virginia Tech, and the McIntire School of Commerce Robertson building and Rouse Hall at University of Virginia. However, while these universities are in Virginia, they are not considered "peers" to Mason.
[53] See information about Washington, D.C.'s Green Roof Subsidy Program: http://www.dcgreenworks.org/index.php?option=com_content&task=view&id=72&Itemid=109

Maryland has partnered with the University of Maryland on many green initiatives[54], and UMD now has at least 4 green roofs.

Policy within the community surrounding a university is also part of their institutional environment. For instance, within the Metro D.C. region, Fairfax County has been vigorously pursuing environmental improvement initiatives for years to prevent degradation of the county's natural resources resulting from its heavy development.[55] In 2008, a 5,000-square-foot interpretive garden was installed on the roof of the Herrity Building parking garage at the Fairfax County Government Center.[56] Fairfax County also adopted a green building standard for all new buildings and renovations in February 2008.[57] All of this activity reflects the importance that the local surrounding communities place on storm water management and water quality in the region.



In a broader context, within the EPA Mid-Atlantic Region (Region 3), the lack of adequate stormwater management is a serious concern, responsible for approximately 5,265 miles of stream impairment (see above chart). (US EPA) The severe impairment of the Chesapeake Bay, which is one of a very small number of estuaries in the world, has created unique social and cultural awareness of the issues of stormwater runoff. Within regional contexts such as these, universities have an opportunity to be local civic leaders by helping to limit development impact on local waterways through the implementation of green roofs and other on-site stormwater management techniques. (Fairfax County, 2008)

[54] *Good Jobs, Green Jobs* National Conference, address by Maryland Governor Martin O'Malley: http://www.governor.maryland.gov/speeches/090206.asp
[55] http://www.fairfaxcounty.gov/living/environment/eip/
[56] http://www.fairfaxcounty.gov/news/2009/fairfax-county-green-roof-wins-award.htm
[57] Fairfax County requires a minimum of a US GBC LEED Silver standard for all government buildings over 10,000 square feet: http://www.fairfaxcounty.gov/news/2008/030.htm

Appendix C: George Mason University's Campus Development History and Reputation

George Mason University in Fairfax, Virginia, has been expanding rapidly since its inception as an independent university in 1972. Over three campuses, the university now owns a total of 804 acres. Although there has not been a total survey completed on how many acres has been developed, the campus went from 4 original buildings in 1958 to 118 buildings on three campuses today. This great expansion has led to an ever-improving reputation. Some examples of public recognition include:

- *US News and World Report's* #1 "Up-and-Coming" university in 2008
- *Princeton Review's* America's 100 "Best Value" colleges for 2009
- *Chronicle of Higher Education's* Great Colleges to Work For survey in 2008
- *Kiplinger's Personal Finance* magazine's national top 100 "Best Values in Public Colleges" list for 2009. According to the magazine, it bases the rankings of public colleges on "a combination of outstanding academic quality plus an affordable price tag."

On the other side of the coin, this expansion has led to conflict with local communities resulting from construction noise and runoff, traffic, and environmental degradation. The university has been proactive in communicating with its surrounding communities on these issues, and has made great strides in focusing master planning efforts on the retention and re-building of green space.[58] However, it is challenging to communicate these strides when framed within a background of bulldozers and backhoes. Symbolic and high-visibility projects enabling the re-greening of campus – like green roof installations – are, this author believes, critical for the reputation of Mason as a community environmental steward. With budgets constantly decreasing, however, it has also become critical to spend operating money on projects with the highest market value.

[58] Conversations with Mason faculty, staff, and students indicate minimally a recognition of, and most often a concern for, the disappearing green space on Mason's Fairfax campus.

Appendix D: Process Summary for Conducting CBA on University Sustainability Projects

Develop the Foundation

- Develop central communication points, mechanisms, and networks, including those with local and regional governments and non-governmental organizations
- Develop strategic communication plan targeted at reducing IA
- Develop representative committee for project review that addresses each potential source of information asymmetry (i.e., include a technical rep, economic rep, academic reps, and external facilitator)
- Develop a standardized project application process and system to collect proposed projects (e.g., environmental management system, ISO 14001)

Conduct Project Assessments

- Identify project: Ensure it aligns with university centers of excellence and strategic goals
- Assemble project team: Develop a strong cross-functional project team for project assessment and (if applicable) execution
- Identify market, non-market, and indirect market costs and benefits: Brainstorm a list of potential costs and benefits, using Table X as starting point; make sure to identify benefits like prestige enhancement, that cannot immediately be quantified, but that are often more critical to the university than the financial outcome
- Conduct Best Practice research: Identify best practices at other universities or institutions with similar institutional environment; seek out academic papers with supporting data; conduct interviews as needed for data collection for benefit transfer
- Develop values for each benefit and cost: Generate a figure, where possible, for a low, medium, and high scenario, where values are uncertain (sensitivity analysis)
- Determine time horizon for project: Select appropriate time horizon to calculate benefits based on expected life of the project's impact on costs and benefits
- Select discount rates and rates of inflation, if applicable: Based on expected source of funding for project; use three values, one of them 0%, one of them a high social discount rate like 8%, and one in the middle based on expected loan or bond rates
- Identify assumptions: Elaborate on assumptions made
- Conduct cost-benefit analysis: Calculate all levels of cost and benefit for each variable
- Final project assessment: Does the project reduce operating costs?
    - If yes, execute project and examine ways to integrate academic and student experiences.
    - If no, does project have the potential to improve reputation in one or more areas?
    - If yes, execute. If no, put aside for future assessment

REFERENCES

REFERENCES

Acks, K. of Cost Benefit Group, LLC. (2005). A Framework for Cost Benefit Analysis of Green Roofs, Initial Estimates. Part of the Green Roofs report completed by the Climate Impacts Group out of the Columbia University Center for Climate Systems Research. http://ccsr.columbia.edu/cig/greenroofs/Green_Roof_Cost_Benefit_Analysis.pdf

Albrecht, P., Burandt, S., & Schaltegger, S. (2007). Do sustainability projects stimulate organizational learning in universities? *International Journal of Sustainability in Higher Education* 8 (4): 403-415.

Astin, A.W., Vogelgesang, L.J., Ikeda, E.K., & Yee, J.A. (2000). How Service Learning Affects Students. UCLA Higher Education Research Institute Report.

Balderston, F.E. (1990). Organization, Funding, Incentives, and Initiatives for University Research: A University Management Perspective. In Hoenack, S.A., & Collins, E. L. (Eds.) *Economics of American Universities: Management, Operations, and Fiscal Environment*, Albany, NY: SUNY Press: pp. 33-52.

Bardaglio, P. & Putnam, A. (Eds.) (2009). *Boldly Sustainable: Hope and Opportunity for Higher Education in the Age of Climate Change*. NACUBO.

Barreiro, J. & Sanchez, M. (2005). How much are people willing to pay for silence? A contingent valuation study. *Applied Economics* 37: 1233–1246.

Baumann, N. (2006). Ground-Nesting Birds on Green Roofs in Switzerland: Preliminary Observations. *URBAN HABITATS* 4 (1). http://www.urbanhabitats.org

Biemiller, L. (2005). Sustainability Tops the Agenda as College Planners and Architects Meet. *The Chronicle of Higher Education* 51 (48): A.25.

Boyle, C. (1999). Education, sustainability and cleaner production. *Journal of Cleaner Production* 7 (1): 83-87.

Bowen, H. R. (1981). Observations on the Costs of Higher Education. *Quarterly Review of Economics and Business* 21(1):47-57.

Braskamp, L. & Wergin, J. (1998). Forming new partnerships in W. G. Tierney (Ed.) *The Responsive University: Restructuring for High Performance*, Baltimore: Johns Hopkins University Press, pp. 62-91.

Carlisle, P. R. (2002). A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development. *Organization Science* 13 (4): 442-455.

Carter, T. & Keeler, A. (2008). Life-cycle cost–benefit analysis of extensive vegetated roof systems. *Journal of Environmental Management* 87: 350–363.

Clark, C., Adriaens, P., & Talbot, F.B. (Sept 2007). Green Roof Valuation: A Probabilistic Economic Analysis of Environmental Benefits. Colloquium Paper, presented on September 10th, 2007 at the University of Michigan Erb Institute for Global Sustainable Enterprise. Accessed on 1/21/08. http://www.erb.umich.edu/News-and-Events/colloquium_papers/Clarketal.pdf

Clune, W.H., & Braden, J.B. (2007). Financial, economic, and institutional barriers to 'green' urban development: The case of stormwater. In Novoty and Brown (Eds.), *Cities of the Future: Towards Integrated Sustainable Water and Landscape Management*, IWA Publishing.

Cohen, M. & March, J. (1974). *Leadership and Ambiguity.* New York: McGraw-Hill.

Cordano, M., & Frieze, I. H. (2000). Pollution reduction preferences of U.S. environmental managers: Applying Ajzen's theory of planned behavior. *Academy of Management Journal* 43 (4): 627-641.

Cortese, A. D. (2003). The Critical Role of Higher Education in Creating a Sustainable Future. *Planning for Higher Education*, March-May 2003, pp. 15-22.

Cronin, M.A., & Weingart, L. R. (2007). Representational gaps, information processing, and conflict in functionally diverse teams. *Academy of Management Review* 32 (3): 761-773.

Cunningham, B.M., & Cochi-Ficano, C.K. (2002). The Determinants of Donative Revenue Flows From Alumni of Higher Education: An Emperical Inquiry. *The Journal of Human Resources* 37 (3): pp. 540-569.

Darnall N. & Carmin J. (2005). Cleaner & greener? The signaling accuracy of U.S. voluntary environmental programs. *Policy Sciences* 38(2-3): 71-90.

Dieleman, H., & de Hoo, S. (1993). Toward a tailor-made process of pollution prevention and cleaner production: Results and implications of the PRISMA project. In J. Schot & K. Fischer (Eds.), *Environmental Strategies for Industry: International perspectives on research needs and policy implications*, Washington, DC: Island Press, pp. 245-276.

Dresner, S. (2002). *The Principles of Sustainability*, Earthscan Publications Limited, London.

Dunnett, N., & Kingsbury, N. (2004). *Planting Green Roofs and Living Walls*. Portland, OR: Timber Press, pp. 23-55.

Fairfax County (2008). Non Point Source Pollution Prevention, Identify and Prevent Non Point Source Pollution. http://www.fairfaxcounty.gov/nvswcd/newsletter/nps.htm

Filho, W.L. (2000). Dealing with misconceptions on the concept of sustainability. *International Journal of Sustainability in Higher Education* 1 (1): 9.

Franz-Balsen, A., & Heinrichs, H. (2007). Managing sustainability communications on campus: experiences from Luneburg. *International Journal of Sustainability in Higher Education* 8 (4): 431-445.

Fuguitt, D. & Wilcox, J. (1999). *Cost-Benefit Analysis for Public Sector Decision Makers*. Westport, CT: Quorum Books.

Gardner, A. (2007 March 15). Eco-Friendly Initiative Proposed for Fairfax: Connolly Tackling Climate Change. Washington Post, A01. http://www.washingtonpost.com/wp-dyn/content/article/2007/03/14/AR2007031402637.html

Getter, K.L., & Rowe, D.B. (2006). The Role of Extensive Green Roofs in Sustainable Development. *HORTCIENCE* 41 (5): 1276–1285.

Hart, S.L. (2005). *Capitalism at the Crossroads: The Unlimited Business Opportunities in Solving the World's Most Difficult Problems*. Upper Saddle River, NJ: Wharton School Publishing.

Herremans, I. & Allwright, D. (2000). Environmental management systems at North American universities: what drives good performance? *International Journal of Sustainability in Higher Education* 1 (2): pp. 168-181.

Hoenack, S.A. (1990). An Economist's Perspective on Costs Within Higher Education Institutions. In Hoenack, S.A., & Collins, E. L. (Eds.) *Economics of American Universities: Management, Operations, and Fiscal Environment*, Albany, NY: SUNY Press: pp. 129-153.

Hoffman, A. (2001). *Competitive Environmental Strategy: A Guide to Changing the Business Landscape*. Washington, D.C.: Island Press, pp. 105-125.

International Greenroof Projects Database. http://www.greenroofs.com/projects/

Ivy, J. (2001). Higher education institution image: A correspondence analysis approach. *International Journal of Education Management* 15 (6/7): pp. 276-282.

James, E. (1990). Decision Processes and Priorities in Higher Education. In Hoenack, S.A., & Collins, E. L. (Eds.) *Economics of American Universities: Management, Operations, and Fiscal Environment*, Albany, NY: SUNY Press: pp. 77-106.

Kadas, G. (2006). Rare Invertebrates Colonizing Green Roofs in London. *URBAN HABITATS* 4 (1). http://www.urbanhabitats.org

Klassen, R.D., & McLaughlin, C.P. (1996). The impact of environmental management on firm performance. *Management Science* 42 (8): 1199-1214.

Kleinberg, E. (Winter 2008). Interdisciplinary Studies at a Crossroads. *Liberal Education* 94 (1): Education Module, p. 6.

Kleniewski, N. & Wooding, J. (2002). Building bridges: sustainable development, interdisciplinary programs and the university. In J.L. Pyle & R. Forrant (Eds.), *Globalization, Universities, and Issues of Sustainable Human Development*, Northampton, MA: Edward Elgar Press (pp. 212-230).

Konar, S., & Cohen, M.A. (2001). Does the Market Value Environmental Performance? *The Review of Economics and Statistics* 83 (2): pp. 281-289.

Kumar, S. (2009 March 10). *Proceedings of MWCOG TAC Meeting: Status of Fairfax County Air Monitors*. http://www.mwcog.org/uploads/committee-documents/k15cXF1c20090309144226.pdf

Lele, S., & Norgaard, R.B. (2005). Practicing Interdisciplinarity. *Bioscience* 55 (11): Research Library Core, p. 967.

Levy, J. & Dilwali, K. (2000). Economic incentives for sustainable resource consumption at a large university – Past performance and future considerations. *International Journal of Sustainability in Higher Education* 1 (3): 252.

Liu, K. & Baskaran, B. (May 2003). *Proceedings of the First North American Green Roofs Conference: Greening Rooftops for Sustainable Communities: Thermal performance of green roofs through field evaluation.* Chicago, IL: The Cardinal Group

McKenzie-Mohr, D. (2000). Fostering Sustainable Behavior Through Community-Based Social Marketing. *American Psychologist* 55 (5): 531-537.

Morris, J. P. (May/June 2005). The Hidden Economics of Campus Sustainability. *Facilities Manager magazine* 21 (3). On APPA website: http://www.appa.org/FacilitiesManager/article.cfm?itemnumber=2316&parentid=2309

Onwueme, I. & Busari, B. (2007). The sustainability asymptogram; A new philosophical framework for policy, outreach and education in sustainability. *International Journal of Sustainability in Higher Education* 8 (1): 44.

Pearce, J.M. & Miller, L.L. (2006). Energy service companies as a component of a comprehensive university sustainability strategy. *International Journal of Sustainability in Higher Education* 7 (1): Education Module, pg. 16.

Peck, S.P., Callaghan, C., Kuhn, M., & Bass, B. (1999). Greenbacks from Green Roofs: Forging a New Industry in Canada: Benefits, Barriers, and Opportunities for Green Roof and Vertical Garden Technology Diffusion. A report prepared for Canada Housing and Mortgage Corporation.

Peck, S.P. & Kuhn, M. (2003). Design Guidelines for Green Roofs. Ontario Association of Architects. http://www.cmhc.ca/en/inpr/bude/himu/coedar/loader.cfm?url=%2Fcommonspot%2Fsecurity%2Fgetfile.cfm&PageID=70146

Porsche, U. & Kohler, M. (December 2003). *Proceedings from RIO 3 - World Climate & Energy Event: LIFE CYCLE COSTS OF GREEN ROOFS: A Comparison of Germany, USA, and Brazil*. Rio de Janeiro, Brazil.

Princeton Review 2009 College Hopes and Worries Survey: http://ir.princetonreview.com/releasedetail.cfm?ReleaseID=324924.

Ready, R., & Navrud, S. (2005). Benefit Transfer – The Quick, the Dirty, and the Ugly? *Choices: a publication of the American Agricultural Economics Association* 20 (3): 195-199.

"Report and Declaration of the Presidents Conference," Talloires, France, 1990.

Rosenzweig, C., S. Gaffin, & L. Parshall (Eds.). (2006). *Green Roofs in the New York Metropolitan Region: Research Report*. Columbia University Center for Climate Systems Research and NASA Goddard Institute for Space Studies: New York.

Roturier, J., & De Almeida, A. (2000). ECOCAMPUS: A 'Practice-What-You-Preach' European Collaboration. In W. L. Filho (Ed.), *Sustainability and University Life*. Frankfurt: Peter Lang, pp. 129-147.

Shriberg, M. (2002). Institutional assessment tools for sustainability in higher education – Strengths, weaknesses, and implications for practice and theory. *International Journal of Sustainability in Higher Education* 3 (3): 254-270.

Stiglitz, J. (1999). Knowledge as a global public good. In I. Kaul, I. Grunberg, & M. Stern (Eds.) *Global Public Goods: Cooperation in the 21st Century*. New York: Oxford University Press, pp. 308-325.

Stewart, N. (2006 November 16). D.C. Moves to Become Pioneer In Forcing 'Green' Construction. *Washington Post*, Page A01. http://www.washingtonpost.com/wp-dyn/content/article/2006/11/15/AR2006111501624.html

Stokey, E. & Zeckhauser, R. (1978). *A Primer for Policy Analysis*, New York: W.W. Norton & Co., pp. 297-308.

Tanzil, D., Murphy, K., Beloff, B., & Hinds, A. (2007). *Proceedings from the American Institute of Chemical Engineers Conference: Assessing the Total Costs and Benefits of Sustainability Projects.* http://aiche.confex.com/aiche/s07/techprogram/P82144.HTM

Turner, R.K., Pearce, D., & Bateman, I. (1993). *Environmental Economics: An Elementary Introduction.* Baltimore, MD: Johns Hopkins University Press, p. 166-170.

United Nations Environment Programme (UNEP), "Declaration of the United Nations Conference on the Human Environment, Principle 19," UNEP, 1972, http://www.unep.org/Documents.multilingual/Default.asp?DocumentID=97&ArticleID=1503

United Nations Educational, Scientific and Cultural Organization (UNESCO), UN Decade for Education for Sustainable Development, http://portal.unesco.org/education/en/ev.php-URL_ID=23279&URL_DO=DO_TOPIC&URL_SECTION=201.html

US EPA Research Highlights – Green Roof Research Project Studies Stormwater Absorbency: http://www.epa.gov/nrmrl/news/news042006.html

US EPA Mid-Atlantic States: Storm Water Pollution Prevention website: http://www.epa.gov/reg3wapd/stormwater/

Velazquez, L., Munguia, N., & Sanchez, M. (2005). Deterring sustainability in higher education institutions. *International Journal of Sustainability in Higher Education 6 (4):* Education Module, pg. 383-391.

Webster, A. & Dautremont-Smith, J. (2009). AASHE Digest 2008: A Review of Campus Sustainability News. *Association for the Advancement of Sustainability in Higher Education*, http://www.aashe.org/highlights/press-releases/digest08

Weick, K. (1976). Educational organizations as loosely coupled systems. *Administrative Journal Quarterly* 21: pp.1-19.

Wong, N.H., Tay, S.F., Wong, R., Ong, C.L., & Sia, A. (2003). Life cycle cost analysis of rooftop gardens in Singapore. *Building and Environment* 38: 499 - 509.

CURRICULUM VITAE

Lenna A. Storm graduated in 1993 with a B.S. in Industrial Management from Carnegie Mellon University in Pittsburgh, PA. Since her graduation, she cut a circuitous path through a variety of careers before arriving at what she believes to be her last and best life-long career working in sustainability. Prior to going back to school full time to pursue her current career, she spent 5 years with GE Financial Assurance. Half of this time was spent as a software quality assurance manager, and half as a Six Sigma Black Belt, where she first caught a glimpse of her future career in the creation of efficient processes. Prior to working with GE, Lenna worked as a web designer and project manager for a small company serving the web marketing needs of the insurance industry, the manager of bakery operations in a small Chicago food market, and a report creator for a small Chicago trading company.