Roxana Elliott
Rosalind Koff
Jen Lennon
Kelley Newman
Dorothy Fang Peng

Greener Heights- Bibliographic Reviews

1) About green roofs. Green roofs for healthy cities. Retrieved March 10, 2012, from http:// greenroofs.org/index.php/about-green-roofs

Green Roofs for Healthy Cities is a non-profit organization that was established in 1999 working to promote the green roof industry throughout North America. They aim to increase awareness of the economic, social, and environmental benefits of green roofs through research, education, and training in green roof implementation. Their activities involve producing a green roof and wall trade show, connecting different green roof organizations, teaching courses on green roofs, and gathering general industry data. As this organization is one of the main proponents of green roofs, their website will be an invaluable source to us.

One of the main objectives of this website is to educate the public about and advocate for green roofs, and their "About Green Roofs" section is extensive. They detail the technology itself, including diagrams of a typical green roof structure, which includes layers of insulation, vapor control, drainage, and the growing medium and vegetation itself. In addition, they list the benefits of green roofs in categories such as waste diversion, stormwater management, moderation of urban heat islands, and air quality improvement, among others. The site also lists the private benefits of green roofs, and notes that energy efficiency and reduced energy costs are a major benefit to an individual building. Green roofs also provide protection against fire spreading, and increases the life of the basic roof as it is protected from the sun and other elements by the "green roof" installed on top.

In addition to their own resources, this website also links to many other green roof organizations, and is updated with new reports on green roofs and infrastructure regularly. As they aid buildings in implementing green roofs, they also provide documents with green roof design standards and specifications, which will be useful for us when describing the technology itself.

2) Getter, Kristin L. & Rowe, D. Bradley (2006). The Role of Extensive Green Roofs In Sustainable Development. *HortScience*, 41(5): 1276-1285. 2006. from: http://hortsci.ashspublications.org/content/41/5/1276.full.pdf

This paper, published in *HortScience,* is a review of current knowledge regarding the benefits of green roofs in sustainable development in the United States. Increasingly, land development has resulted in supplanting forests, agricultural fields, suburban and urban terrain with impervious surfaces. The necessity to recover green space is becoming increasingly critical to maintain environmental quality in the U.S.. Implementing green roofs is one potential remedy for this problem.

The paper points out that there are numerous ecological and economic benefits, such as storm-water management, energy conservation, mitigation of the urban heat island effect, increased environment

in which to work and live, shading and insulation benefits, and control of noise and air pollution. Additionally, the construction and maintenance of green roofs provide business opportunities for nurseries, landscape contractors, irrigation specialists, and other green industry members.

The paper contributes a general understanding that in North America, the concept of green roofs is just now being introduced and will likely become more common in the future. They represent an entirely new market for nursery stock and landscape contractors, and the potential market consists of all existing and future roofs in the country.

3) Kokogiannakis, George, Annegret Tietje, and Jo Darkwa. "The Role of Green Roofs on Reducing Heating and Cooling Loads: A Databate across Chiense Climates."*Procedia Environmental Sciences* 11 (2011): 604-10. *Www.pubmed.gov*. Web. <http://ac.els-cdn.com/S1878029611009170/1-s2.0-S1878029611009170-main.pdf?_tid=ea9dae3f0e234cebc3a13060bc7e4258&acdnat=1333026505_80c4bcff8591594a410605f8e4175583>.

Summary: This study looks at modeling techniques to develop a database for an efficient and user-friendly way to access energy performance of green roofs across a variety of Chinese climates, where many green roof solutions are already in place. The main variables in this research are heating and cooling loads, which are calculated through the use of an Energy-Plus tool for indoor temperatures. This article reviewed 5328 different configurations of green roof technologies by changing parameters such as location, climate, seasonal periods, glazing type, wall insulation levels, roof insulation, soil thickness and condition, and vegetation density characteristics. The results show that green roofs absolutely offer significant heating and cooling solutions and savings when applied to roofs without insulation, but only limited energy savings when there is already heavy insulation in place on a roof. This tool may be used for building purposes where a quick reference for energy saving initiatives or heating and cooling strategies are considered.

Relevance: This article is beneficial to our green roof research as it gives us an example of the upcoming methods toward making green roof technologies more accessible and easier to implement in a variety of climates.

4) Martin, A. (2005). *Green roof manual*. Retrieved from http://www.pomegranate.org/wp-content/publications/Pomegrante-Center-Greenroof-Manual-2005.pdf

Alyssa Martin presents a how-to guide for property owners interested in converting their conventional roofs into green (or living) roofs. The manual addresses the costs and benefits of living roofs and provides a list of resources and materials for homeowners local to the Pomegranate Center, the non-profit organization who published this manual. It also offers an explication of the physical structure of a green roof, detailing the various components of its makeup, and advising on the conversion process.

This guide outlines the chief advantages to green roofs, including the reduction of storm water runoff, improved quality of water entering local watering systems, heat reduction for both the building and urban surroundings, reduction of air pollutants and improved air quality, building insulation, creation of protective habitats for migrating species, and reduction in noise and glare.

The manual also provides key considerations and cost factors related to installing and maintaining a green roof. It notes that green roofs endure approximately 20 years longer than traditional roofs and, over time, will save homeowners considerable expense. Martin mentions that installation costs may vary depending on the type of system installed, size of the roof, thickness of growth media, types of plants used, and type of irrigation system. She specifies that chief considerations for planning a green roof include the slope of the roof, climate, local zoning and community regulations, insurance and building structure. Further, Martin provides examples of mistakes to avoid in green roof implementation.

The guide provides a diagram illustrating a cross-section of how a green roof is configured, and details the functions and constitution of each layer. Martin advises on required materials and recommended quantities for each component of the system. Finally, a list of local vendor resources is provided. This bibliographic source is valuable from multiple perspectives. It provides insight as to the physical construction and composition of green roofs, technical and logistical considerations related to green roof conversion and maintenance, the fiscal implications of green roof implementation and the extensive range of benefits green roofs offer to home, community and environment.

5) Martin, B. (2012, February 28). Lofty ambitions: why green roofs are the future of urban gardening. Ecologist, Retrieved from http://www.theecologist.org/green_green_living/gardening/1261593/lofty_ambitions_why_green_roofs_are_the_future_of_urban_gardening.html

Ben Martin explained what green roofs are, the benefits of green roofs, and how they work for the readers of Ecologist, which is a part of the Guardian Environmental Network. Martin said that green roofs are actually quite common in the United Kingdom, actually dating all the way back to the Vikings, but it's only now that building codes and regulations have caught up. From large corporate buildings such as Rolls Royce to personal homes, Martin posits that green roofs are the way to go based off of several factors.

He talked to Jim Blundell, a sedum and plantation expert, who explained many of the environmental benefits of green roofs. But first, Martin explained the environmental benefits of green roofs by saying that they can reduce CO2 emissions, and with buildings contributing to 50% of the UK's CO2 emissions, that could be a real help for air quality. Green roofs also reduce storm water runoff, increase biodiversity by providing a habitat for insects, birds, and butterflies, and lessens the impact of the urban heat island effect.

Another benefit of green roofs, Martin continued, is in savings for the building owners because green roofs increase a roof's lifespan and can reduce energy bills. While green roofs can help in the winter by adding extra insulation, the real savings occur in the summer when the green

roof
absorbs the heat, instead of a normal roof which would then transfer that heat into the building.

He interviewed Dusty Gedge, wildlife consultant and green roof expert, who expounded on many of the environmental benefits mentioned above, but also spoke to the aesthetic pleasure of
green roofs and mentioned that he loves seeing his green roof each day.

Jeff Sorrill, project manager of the Green Roofs Centre at the University of Sheffield told Martin
that in Sheffield County, buildings that exceed a certain size have to include at least 80% of vegetated cover, so now government buildings, libraries, and new schools will feature green roof
space.

Finally, Martin spoke to Gedge and Blundell about the practicality of green roofs and what it takes to actually install one. Gedge warned that interested homeowners shouldn't just go and grab the first materials they see. There needs to be research done to find the best plant for each
home and climate, just as with any plant. Green roofs come in "intensive" and "extensive" varieties. Extensive roofs consist of a thin stratum of soil and rock wool, which supports small but hardy plants and mosses. Extensive roofs are lightweight and lower cost, and don't require a
ton of upkeep, save for a "haircut" every year. Intensive roofs have a thicker layer of soil that can
support a wider variety of plants, including lawn grass or even trees. The intensive roofs are more expensive, though, and more high maintenance. Blundell noted that while there are a lot of
different ways to do green roofs, including different thicknesses and plants, it does require taking
a look at the kind of roof first to make sure the green roof won't slide off. Blundell recommended
having a structural engineer look at the roof first.

Overall, this article takes a comprehensive look at green roofs, particularly in the United Kingdom, and the author talked to multiple sources within the environmental sphere in the UK
and Sheffield County. This provides a nice overview of green roofs, as well as insight into how another country is using them, especially a country that has been using green roofs for a very long time, even before the government started providing regulations for them.

6) Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R. R., Doshi, H., Dunnett, N., Gaffin, S., & Köhler, M., Liu, K., Rowe, B.(2007). Green roofs as urban ecosystems: Ecological structures, functions, and services. *BioScience*, *57*(10), 823-833. doi: http://dx.doi.org/10.1641/B571005

Oberndorfer, et al. discuss the benefits green roofs offer ecosystem services in urban areas, such

as improved storm-water management, reduced urban heat-island effects, more efficient building temperature regulation and energy conservation, heightened fire resistance, air quality improvement, and increased wild life habitat. This literature examines evidence for these advantages, gives an overview of the history of green roofs and illuminates how the structure of a green roof determines its functions. Further, it discusses the relationship between these aspects and the surrounding ecosystem.

This article defines, compares and contrasts different types of green roofs – specifically, "intensive" and "extensive" green roofs. Intensive green roofs are often utilized to maximize additional living and recreation space and are more elaborate and aesthetic than extensive roofs. They are typically regarded as a roof-top garden comparable to a conventional, landscaped garden at ground level. Intensive gardens tend to be easily accessible, require more maintenance and are more costly to sustain than extensive green roofs. In contrast, extensive green roofs are strictly functional in nature, implemented for storm water runoff management, fire prevention and insulation. They are commonly not as accessible as intensive roofs as they are not considered an addendum to living space. Aesthetically, they are not particularly elaborate and tend to have a shallower substrate than intensive roofs.

The article continues to illustrate the different facets of an extensive green roof and the various types of extensive green roof technology, including complete systems, modular systems, pre-cultivated vegetation blankets and inverted systems. The authors then address the key ecological benefits (storm water runoff management, energy conservation and urban habitat provision) these features enable. This literature also suggests a number of possible research directions for further exploration of this technology, including cost-benefit models, biodiversity studies, air quality and water quality.

This article is a useful resource because it provides an overview of the origin and nature of green roofs, the variations in green roof type and the different architectures within a given type. Further, it explores the varied benefits of a green roof and how its components contribute to these advantages. The authors provide insight as to how green roofs could be examined through the lenses different research disciplines. In particular, it stresses how interdisciplinary research can better our understanding of the relationship between constructed ecosystems and the larger urban environment.

7) Sonne, Jeffrey (2006). Evaluating Green Roof Energy Performance. *ASHRAE Journal.* Vol. 48, February 2006. from: http://www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1659-06.pdf

This is an academic paper using a case study to evaluate the energy performance of green roofs. At the start the paper, the author gives some introduction and background of this technology. Green roofs have been in use in Europe for centuries. Germany has emerged as a leader in modern green roof technology and usage where it's estimated that there are more than 800 roofs that comprise 10% of all flat roofs. The author also states that, in recent years, green roofs are also becoming more popular in the United States. Chicago City Hall and Ford Motor Company Dearborn truck plant are two high profile examples that each have total green roof area of more than 10 acres.

The paper explains several advantages of green roofs. In addition to the rainwater runoff reduction and aesthetic benefits, the most important benefit of a green roof is its capacity of significantly reducing roof surface temperatures and heat flux rates. The paper evaluates a study of a green roof installed on a two-story building addition focusing on roof temperature and heat flux comparisons between the conventional, light-colored membrane half of the roof and the green roof. The results of the research show that the maximum average day temperature seen for the conventional roof surface was 130°F while the maximum average day surface temperature for a green roof was 91°F. The data indicate significantly lower peak roof surface temperatures and higher nighttime surface temperatures for the green roof.

8) Susca, T., S. R. Taffin, and G. R. Dell'osso. "Positive Effects of Vegetation: Urban Heat Island and Green Roofs." *Environmental Pollution* 9th ser. 159.8 (2011): 2119-126. *Www.pubmed.gov*. Web. <http://www.ncbi.nlm.nih.gov/pubmed/21481997>.

Summary: This article looks at the range of effects of vegetation based on a scale of urban rating and building size. The study was held in New York City, and found that the most vegetated areas of the city were about 2°C cooler than those areas that replace vegetation with man-mad materials. Additionally, the research used a climatological model to studied climate in these areas, and compared the surface albedo (or light radiation), the construction, and the use of either a black, white, or green roof. In this part of the study, black roofs had the greatest impact in raising temperature, and the green roof played a large role in surface albedo as the biological activities of the plants played a large regulatory role.

Relevance: This article discusses some of the fundamental technical applications of the green roof phenomenon. It lays out basic facts to support the concept of green roofs, and the implementation of this system in any landscape - especially a richly urban area.