

THE CHARACTERISTICS & BENEFITS OF GREEN ROOFS
IN URBAN ENVIRONMENTS

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Green Roof square footage has increased 72 percent (from 1.3 million to about 2.5 million square feet) in North America between 2004 and 2005 with more than 80 percent in the United States alone, according to a report published last April from Green Roofs for Healthy Cities which is a trade group of developers and building material suppliers dedicated to the further improvement of the green roof infrastructure industry (Burnham 2006). With the greening of our urban rooftops seeming to take hold in many of our major cities throughout North America, I would like to examine some of the characteristics and benefits of green roofs within these environments.

Let me begin by giving a general definition of a “Green Roof”. I would describe this as an engineered roofing system that includes vegetation planted in a growing medium above an underlying waterproof membrane material. It has also been referred to as a living roof or ecoroof, to differentiate a vegetative extensive roof specifically from other types of sustainable roofs such as those covered with photo voltaics or highly reflective roofs (white roofs), which are often included in the broader environmental term of green or sustainable roofing systems.

There are basically two main categories of newer, contemporary vegetative, green roof systems being used today. They are *extensive* and *intensive*. An extensive system typically has from one and a half to six inches of substrate or planting media and typically is not suitable for foot traffic or occupancy. The additional weight of this type of system is generally within the normal load-bearing capacity of most roof structures today, usually increasing the load by 14 – 35 pounds per square foot. Some typical plant types that are best suited for extensive ecoroofs are simple sedums & mosses, as well as low growing, drought tolerant plants which include many perennials, grasses & wildflower mixtures. They usually require minimal maintenance or additional irrigation. Without additional moisture, many may “brown-out” during a dry season, eventually reviving once the rains return.

An intensive roof system is very much the same as older style gardens found on rooftops, which were accessible to people to enjoy much like traditional gardens. They generally have a deeper, soil-based substrate from eight to twenty-four inches in depth allowing for greater plant diversity. Additional options for plant species would include medium size shrubs and grasses, as well as edible garden plantings, small trees, and often stone paving or walkways. As you would imagine with this type of vegetative roof system there is a need for greater structural support, with additional load ranging from 59 – 199 pounds per square foot. Also with greater plant varieties and deeper substrate, these ecoroofs are more likely to remain green during dry seasons and more likely to be irrigated – depending on plant variety, location and depth of soil.

Much has been written about the benefits of green roofs and they typically are divided into three main categories - *aesthetics / amenities*, *environmental* & *economic*. It is important to note that there can be cross-over among these categories. For example, edible roof top gardens provide an economic benefit, by producing food on site, thus reducing the added cost of transporting food over longer distances, as well as an environmental benefit by lessening pollution from vehicle use for trucking. Another way to describe the advantages of a green roof is in *public* or *private* terms which are often used to market the idea based upon a target group. For example, the private benefit of savings in energy costs might be used to promote the monetary advantage of an ecoroof to a homeowner.

In terms of aesthetics and amenities as a benefit of ecoroofs, we should first consider the view looking down on a typical urban roofscape. Most are far from attractive – often a varied mix of stark, hard surfaces made up of mostly tar or asphalt and often including exposed plumbing and mechanical systems. A green roof on the other hand provides surrounding upper story occupants a more attractive sight than the typical roof makeup, thereby offering a number of possible therapeutic effects, such as stress reduction, lowered blood pressure, relief of muscle tension, and increased positive feelings. The developers of a three story Hawthorne condominium/commercial building in Portland, Oregon included an ecoroof on top of the first story area, creating in effect a visual “front yard” for the residents, stemming in part from neighborhood requests for the inclusion of green elements in the design (City of Portland, ES 2006).

Some other beneficial amenities that might be found on intensive (accessible) roofs are the opportunity for recreation, such as eating / barbecuing, dog walking, and reading, as well as on-site food production. An example of the latter is the Hawthorne condominium building I mentioned above which provides residents the use of accessible herb garden area. Also, a larger scale example of food production can be found on the roof of the Fairmount Hotel in Vancouver, BC, which has 2,098 square feet of garden area that produces the herbs used in the hotel restaurant, resulting in savings of \$20-25,000 on food costs per year plus being able to recoup in the first year most of the \$25,000 initial cost for the re-roofing renovation (Paladino & Co. 2004).

In addition to the aesthetical and amenity advantages of a green roof, I want to describe and evaluate three of the many environmental and economic benefits – storm water management, protection of roof membrane / increased roof life, and reduced heating / air conditioning costs. Eco-roofs can be effective as a part of storm water management strategy in decreasing run-off (which very often picks up contaminants along the way) into storm systems by allowing rainfall absorption into the growing medium and plants. According to a study from the City of Portland, Bureau of Environmental Services 2 years of data (from 2002 & 2003) showed that an ecoroof of 25-psf with 4-5 inches of substrate has a precipitation retention of approximately 69%. Also, it was noted that during the dry season nearly 100% of the rainfall was held in the substrate (Hutchinson 2003). To further encourage storm water management, the city is initiating a program this fall allowing discounts up to 35% on municipal storm water fees to homeowners and businesses who have installed qualified ecoroof systems on their home or building. For structures in the Central City Plan District where a qualifying ecoroof had been installed, a developer is eligible to receive bonus FAR (floor area ratio) based on three ranges of living roof coverage. They are: 10-30%, 30-60%, and 60% plus which earns one, two and three square feet respectively of additional floor area per square foot of ecoroof (City of Portland, OSD 2006).

A second economic benefit of using a green roof system is the protection of roof membrane and increased roof life. There are many whose initial reaction to an ecoroof would be that it would leak and therefore allow moisture to penetrate into the building. Actually, the opposite has shown to be true. If the appropriate construction methods are used, vegetative rooftops are typically longer lasting than those utilizing conventional roofing methods and materials. Green systems have been shown to extend roof life from two to three times that of a traditional system which have an average life of fifteen to twenty years. Some green roofs in Germany have lasted as long as forty years.

Planted roofs can actually protect a roof membrane from intense ultra violet degradation and expansion and contraction from temperature extremes, thereby enhancing their long term performance. This is demonstrated in a study lead by the National Research Council Canada (see charts & graphs following on pages 6-8) that measured both thermal performance and energy efficiency of a green versus conventional roof. (Liu, n.d.) The location for the study was the Field Roofing Facility constructed on their Ottawa campus. The roof area was 778 square feet representing a low-slope industrial roof with high roof to wall ratio and divided into two areas with a parapet median. On one side, a generic extensive green roof that included a wildflower meadow mixture planted in 6" of lightweight medium was used. A modified bitumen roof system was used as the reference side and included light gray granules as a cover.

Both sides of the roof were instrumented to determine temperature profile of the systems, solar reflectance of the roof top, heat flowing across the system, soil moisture content, microclimate created by vegetation, and the storm water run-off. Meteorological data was collected from weather stations on the center median and at 165 feet away from the structure. Data collected from the first year was analyzed and compared to determine the thermal performance of both roof systems. Sensors used for monitoring were connected to a data acquisition center.

Looking at the graph (NRC Canada – Figs. 2 & 3) representing the daily temperature fluctuation of the roof membranes, we can see that the ecoroof had a lower temperature variance than the reference roof on a summer day, due to the plant shading, insulation and evapotranspiration from the green vegetative system. The outside temperature peaked at 95 F, while the green roof membrane remained around 77 F and the reference roof reached 158 F from solar absorption. On the other hand, the winter months of January & February showed very little temperature variance for both roof systems due to the mass and insulation from the snow cover. Overall, the median daily membrane temperature differences between the two systems are important to note in regards to membrane protection and extending roof life. For example, Liu noted in the NRC Canada study that:

Heat exposure can accelerate aging in bituminous materials. In the roofing industry, heat aging commonly is used as an accelerated aging test for bituminous materials, such as for ASTM D5869, "Standard Practice for Dark Oven Heat Exposure of Bituminous Materials." UV radiation can change the chemical composition and degrade the mechanical properties of bituminous materials. (p. 5-6).

Since the green roof has done a better job of reducing the temperature fluctuation of the roof membrane, one can assume that this roof would have an extended life compared to the reference roof where higher temperature fluctuations have occurred during the spring and summer months.

Another important economic benefit of green roofs is reduced heating and air conditioning costs. The energy demand for the interior space heating or cooling is determined by heat flow through the building envelope. From the same NRC Canada study above, a graph (Fig. 4) showing average daily energy demand caused by heat flow through the roof surface, we see that the green roof significantly outperformed the reference roof from May through September (2001). The reference roofs absorption of solar radiation from greater exposure to the elements and heat gain, and re-radiation of the absorbed heat at night, created a higher daily energy demand. Contrary to this, the ecoroof system through the benefit of plant shading, plant & soil insulation and evaporative cooling, acted as a thermal mass, which lessened heat exchange through the system. There was only a slight difference between the two systems in the fall. The graph further shows

almost identical energy demands during the winter when snow coverage also provided insulation to the reference roof, thereby equalizing the heat flow for both sides. The result of this study shows that energy savings on space conditioning are most significant in the spring & summer. Looking at the average daily demand for space conditioning for the two systems, we see the reference roof at 20,500 – 25,600 BTU (6 – 8 kWh) versus the green roofs average of less than 5,100 BTU (2 kWh) – a reduction of over 75%.

In North America these past few years we have watched green roofs become a fast growing and innovative technology in our quest for creating more sustainable communities and environments. Gaining a better understanding of their characteristics and value will most certainly help us improve their performance and extend their applications. With further study and evaluation of existing rooftops and improvements in the design of roofing systems and materials, substrate mixes, and plant varieties, we can continue to enjoy our ecoroofs for years to come. I have touched on only a few of their advantages, from aesthetics and recreation to reducing storm water run-off into our waterways and energy and material costs to our homes and businesses. I believe this is a viable technology and look forward to further research into its myriad possibilities. I am anxiously waiting to receive a just released book focusing on vegetation for green roofs. It is titled “Green Roof Plants – A Resource & Planting Guide” (Timber Press, Portland, Oregon) by Edmund C & Luci L Snodgrass. He has started the first green roof nursery in the United States and is very involved in consulting and collaborating on research for ecoroof vegetation. Who knows, it may not be too long before we can buy these products from our local home improvement stores as a roofing material!

Graphs & Charts from
 National Research Council Canada Study by Kim Liu Ph.D.
 Professional Roofing Magazine – September 2002



Photo courtesy of the National Research Council Canada, Ottawa.
A green roof system was built on the Field Roofing Facility at the National Research Council Canada's campus in Ottawa. The wildflowers growing on the green roof system are native to Ontario or adapted to its climate.

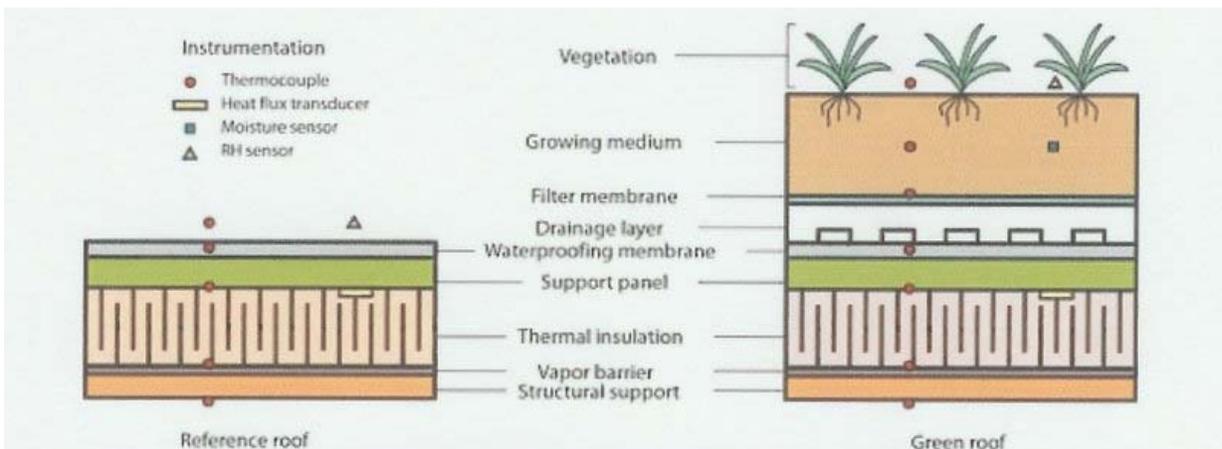


Figure courtesy of the National Research Council Canada, Ottawa.
Figure 1: Major components and instrumentation of the green roof system and reference roof system are shown.

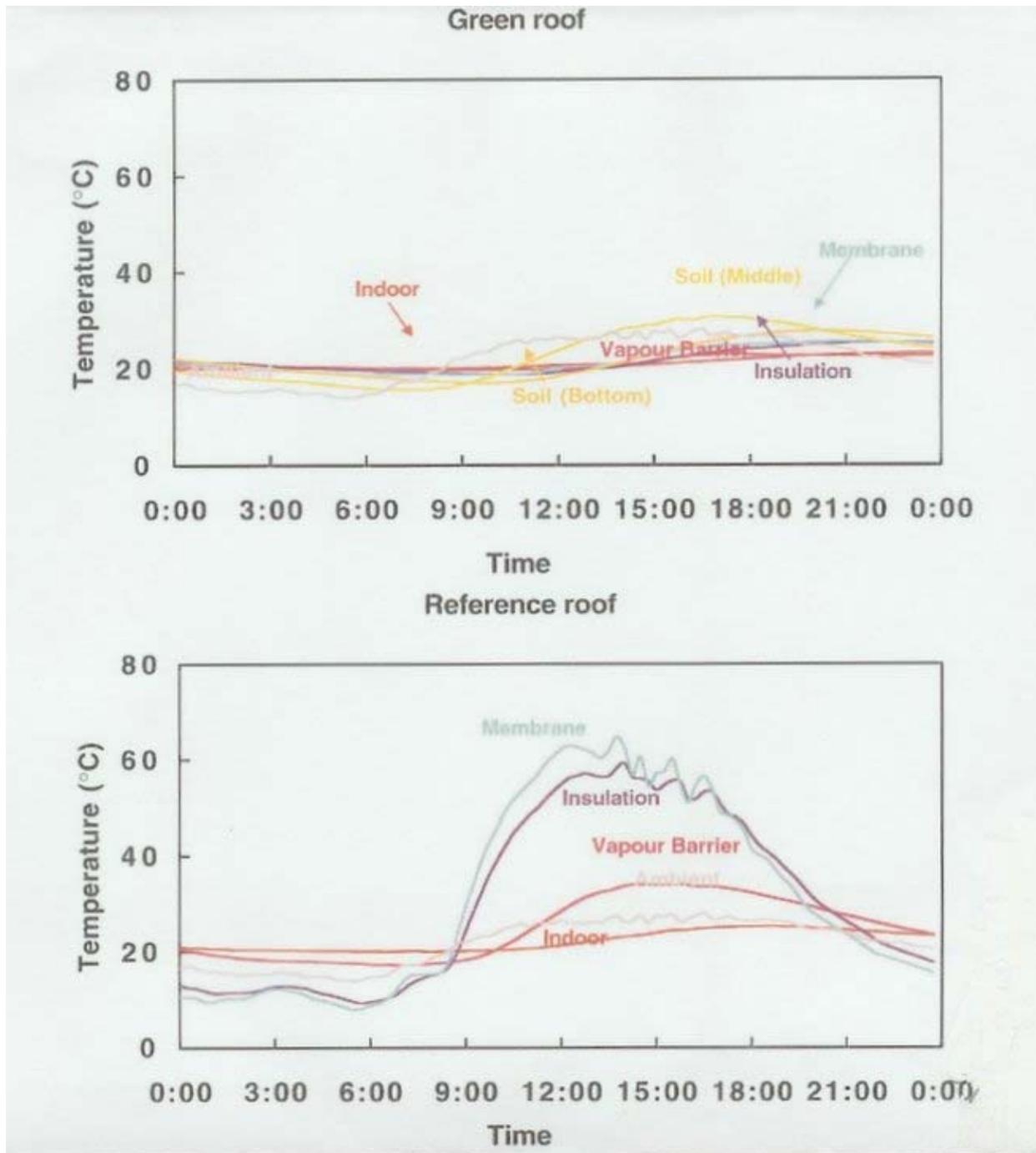


Figure courtesy of the National Research Council Canada, Ottawa.

Figure 2: A temperature profile within the roof systems on a hot, sunny summer day indicates the green roof system reduced its temperature fluctuations.

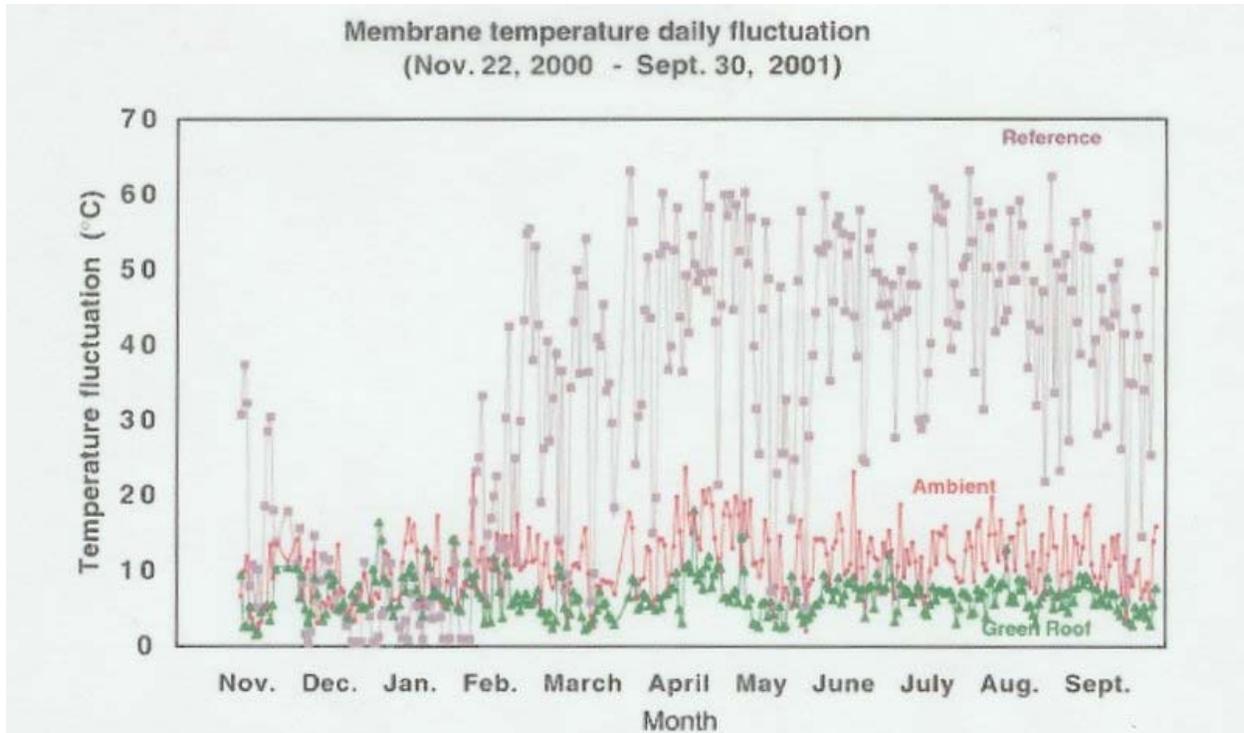


Figure courtesy of the National Research Council Canada, Ottawa.

Figure 3: Temperature measurements show the green roof system significantly reduced the daily temperature fluctuations experienced by its roof membrane.

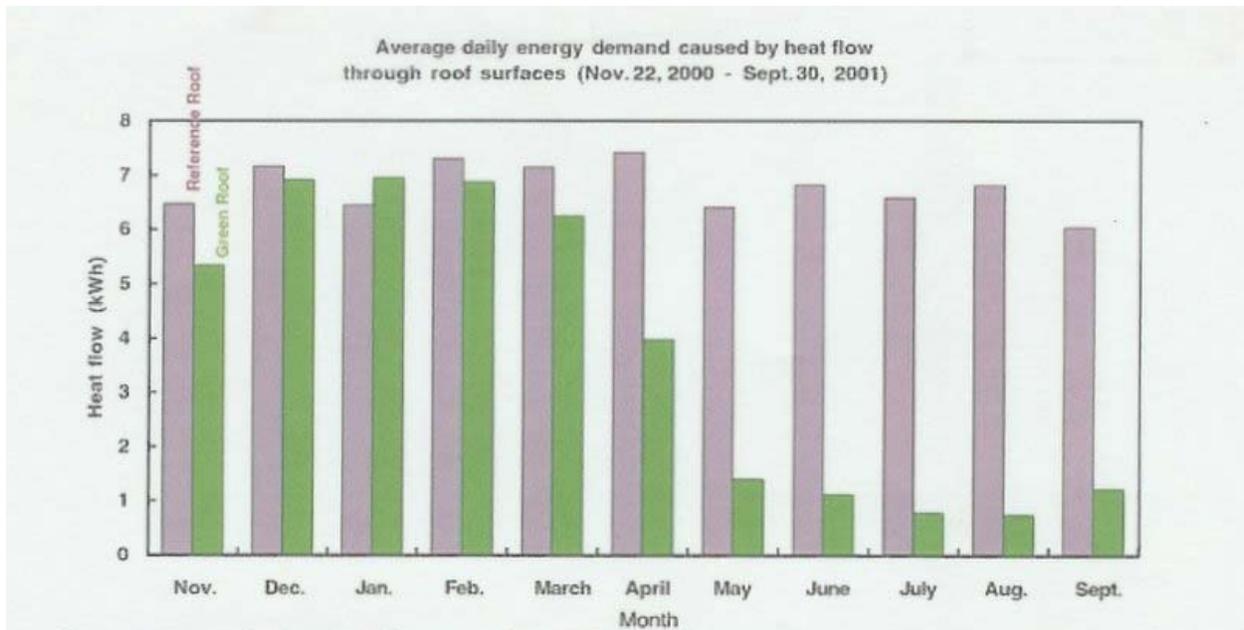


Figure courtesy of the National Research Council Canada, Ottawa.

Figure 4: Heat-flow measurements show the average daily energy demand caused by the heat flow through the green roof system was less than that of the reference roof system in spring and summer.

References

- Liu, K, Ph.D. (n.d.). *A National Research Council Canada study evaluates green roof systems' thermal performances*. Going Green - September 2002 - Professional Roofing Magazine. Retrieved October 5, 2006 from http://www.professionalroofing.net/article.aspx?A_ID=130
- Hutchinson, D., Abrams, P., Retzlaff, R., & Liptan, T. (2003). *Stormwater Monitoring Two Ecoroofs in Portland, Oregon, USA*. City of Portland, Bureau of Environmental Services. Retrieved October 17, 2006 from <http://www.portlandonline.com/shared/cfm/image.cfm?id=63098>
- Paladino & Company, Inc. (2004). *Green Roof Feasibility Review*. Retrieved October 11, 2006 from http://www.metrokc.gov/dnrp/swd/greenbuilding/documents/KCGreenRoofStudy_Final.pdf
- Dunnett, N., Kingsbury, N. (2004). *Planting Green Roofs & Living Walls*. Portland, Oregon: Timber Press
- Burnham, M., (2006). *Green Roofs Grow*. Sustainable Industries Journal – Green Building – Green roofs grow. Retrieved October 11, 2006 from <http://www.sijournal.com/greenbuilding/2858341.html>
- City of Portland, Oregon, Office of Sustainable Development (2006). *Ecoroofs*. Retrieved October 17, 2006 from <http://www.portlandonline.com/osd/index.cfm?c=42113&a=114728>
- City of Portland, Oregon, Environmental Services (2006). *Portland Ecoroof Tours*. p 18. Retrieved October 11, 2006 from <http://www.portlandonline.com/shared/cfm/image.cfm?id=53988>