Green Roofs and Sustainability

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Abstract: While they are not widely seen today in the United States, green roofs offer many benefits at both the single building level, as well as at the city level. These benefits included reduced heating costs for building owners, as well as a reduction in storm water runoff and the urban heat-island effect. However, green roofs may not be best suited to every building, as retrofitting of green roofs must take into account several characteristics of an existing building, most important of which is the amount of weight that the roof can support.

About 360Chestnut:
360Chestnut is an online resource dedicated to energy efficiency. Our goal is to be a one-stop information resource tool for the consumers to determine the most cost-effective energy efficiency improvement projects for their homes, discover available rebates and incentives, and connect with a local certified service contractor who will perform the work. Here at 360Chestnut, we help you to Save Energy, Save Money, and Live Better.

Check out our blog for most up-to-date information on home energy efficiency at http://www.360chestnut.com/blog. If you have any questions about home energy efficiency, ask one of our experts by emailing info@360chestnut.com. We love to hear from you.

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While cities are oftentimes leaders in sustainability, the density and intensity of development that typifies them is often linked with their most unsustainable aspects. For example, land-use in cities is often much more efficient than more rural areas, but it is just this density of buildings that leads to the urban heat-island effect, which in turn leads to more pollution and energy use from cooling. The same is true for storm-water management; land-saving density leads to unsustainable management of water. It is at the convergence of these density-related issues with energy efficiency that green roofs can be implemented to potentially solve these environmental issues.

Simply put, a green roof is a roof that is partially or completely covered by vegetation and a growing membrane. This can mean many different things depending upon the building and the goals of the gardener. There are several types of green roofs available, and they can range from small sedum plants growing in 2" of soil to grasses, shrubs, and trees growing in more than 8" of soil to a small-scale rooftop farm that actually produces food. Of course, a green roof cannot be implemented anywhere without a serious consideration of their benefits, needs, and risks. However, 14% of flat rooftops in Germany were green roofs (Castleton, et al.), so, unless the $77 million in green-roof investment in the country has been misspent, there are a broad range of situations in which green roofs are relevant as sustainability measures.

Green roofs do indeed yield many advantages for their owners, perhaps the most significant and noticeable of which is energy saving. Green roofs have been shown to reduce both cooling demand in the winter and cooling demand in the summer, though the extent to which this is true depends upon the specific place in which they are implemented. After a study of the performance of green roof systems in Toronto, Lui and Minor note that they,

> "… consistently reduced the average daily heat flow through the roof throughout the year – more in the summer (70-90%) and less in the winter (10-30%). This again confirmed that extensive green roofs could improve the energy efficiency of the roofing system, particularly effectively in reducing heat gain in the summer. In the first year of monitoring, the green roofs reduced the total annual heat gain through the roof by 95% but the heat loss by only 23%."

However, it is important to note that the performance of green roofs varies not only with climate, but also with the amount of insulation on the roof of the house below the green roof. In fact, green roofs can slightly reduce heating efficiency in certain climates on roofs that are already very well insulated, though by a very small amount. While this may be the case, on the same home that saw slight heating efficiency reductions saw an overall reduction in heating energy requirements (Jaffal, et al.).

Insulation Level (cm)	Mean Indoor Air Temperature (°C)		Maximum Indoor Air Temperature (°C)		Heating Demand (kWh m^{-2} $year^{-1}$)		Cooling Demand (kWh m^{-2} $year^{-1}$)		Total Energy Demand (kWh m^{-2} $year^{-1}$)	
	Conventional Roof	Green Roof	Conventional Roof	Green Roof	Conventional Roof	Green Roof	Conventional Roof	Green Roof	Conventional Roof	Green Roof
0	29.3	22.8	33.8	24.5	133.6	69.8	7	0	140.6	69.8
5	28.4	25.4	30.1	27.1	45.6	43	2.5	0	48.1	43
10	28.4	26.4	30.1	28	36	36.1	2.5	0.1	38.5	36.2
15	28.4	26.9	30	28.5	32.4	32.8	2.5	0.4	34.9	33.2
20	28.4	27.1	30	28.8	30.5	31	2.5	0.7	33	31.7
25	28.4	27.4	30	29	29.3	29.8	2.5	0.9	31.8	30.7
30	28.4	27.5	30	29.1	28.5	29	2.5	1.1	31	30.1

This table shows the energy use impacts of a green roof in La Rochelle, France

In addition to efficiency improvements, green roofs have several positive effects that are less noticeable at the level of a single roof, but certainly would have a noticeable positive impact should they be widely implemented in an area. Firstly, green roofs help reduce the urban heat-island effect. This is described by Castleton, et al.:

> "...in warm conditions the heat in a bare roof accumulated from the day continued to enter the building during the night. Planted roofs suffered less heat gain during the day... it was found that after sunset the ambient air temperature above the vegetation was reduced significantly and continued to cool the ambient air throughout the night."

As noted above, green roofs do not store and radiate heat in the same way as conventional roofs thus they reduce the temperature directly

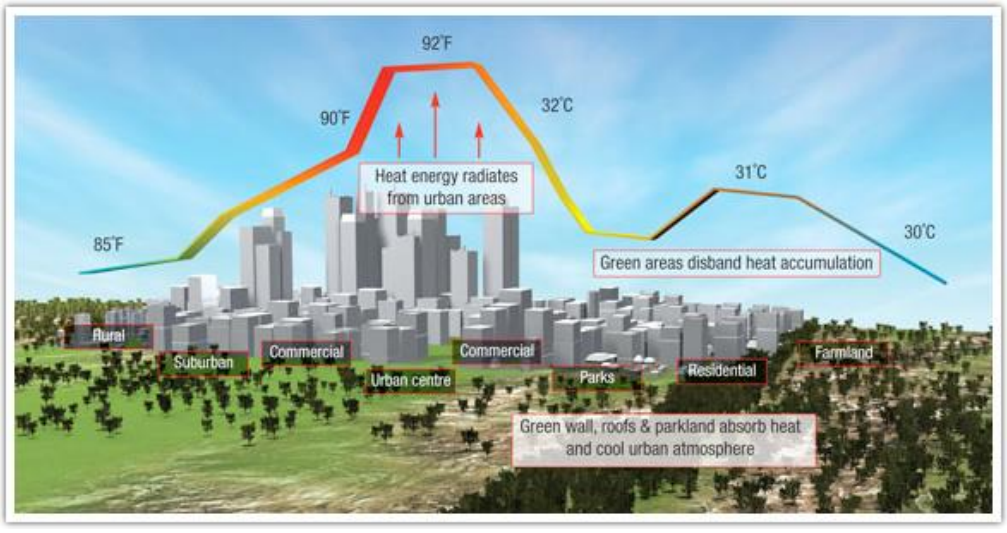

Illustration of the urban heat-island effect

around the building and reduce the urban heat-island effect. Secondly, green roofs store CO2, a known driver of climate change. Though individual green roofs with small plants like sedum do not store large amounts of CO2, conventional roofs store no CO2 at all. Moreover, if green roofs are widely implemented, CO2 reductions would be significant; if every roof in Detroit was converted to a green roof, it would offset the CO2 emissions of 10,000 SUV's (Alter). Thirdly, green roofs help to manage storm water in a way conventional roofs do not, reducing storm-water runoff and keeping our waterways cleaner (Apex). Finally, green roofs reduce wear on roofs and can actually increase the life of the roof (EPA).

While they bring with them many benefits, green roofs may not be suitable for every roof. A green roof can put undue strain on a roof that was not designed to support a lot of weight. Green roof systems vary greatly in depth and the types of vegetation they can support, and thus their weight can vary greatly as well. The lightest systems weight between 25 and 30 pounds per square foot when wet and can only support small plants like sedum and perennials, while heavier systems can support vegetation as large as trees and can weigh over 100 pounds per square foot when full saturated (Stater). It is also important to keep in mind that some types of green roofs may not be appropriate for roofs with a steeper pitch.

Additionally, green roofs can be costly upfront, even if they have long-term benefits. A relatively shallow extensive system, which would likely be most appropriate for a single-family or small multi-family building costs approximately $8-$15 per square foot (Apex). Though a properly installed green roof should require little maintenance and last for many years, roofs that are not installed properly come with the risk of leaks, which can be very costly to repair. This has led to questions of whether or not a green roof is a smart choice for building owners. However, leaks and water damage should not be a concern for quality systems that are properly installed.

Green roofs offer many benefits in areas they are installed. They improve energy efficiency while reducing the urban heat-island effect, help with storm-water management, offset carbon

emissions, and even make roofs last longer. They can be costly upfront to install, their installation is accompanied by many long-term savings. Some municipalities offer rebates for the installation of green roofs, but there is not currently a federal incentive program in the United States for installing green roofs. There have also been questions of whether or not they are even a good idea, as a leak in the waterproof membrane could be extremely costly, though a properly installed system should be safe from any leaks. Indeed, green roofs are tools that can be used to make cities more sustainable at the confluence of the problems of energy efficiency, the urban heat-island effect, and storm-water management.

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