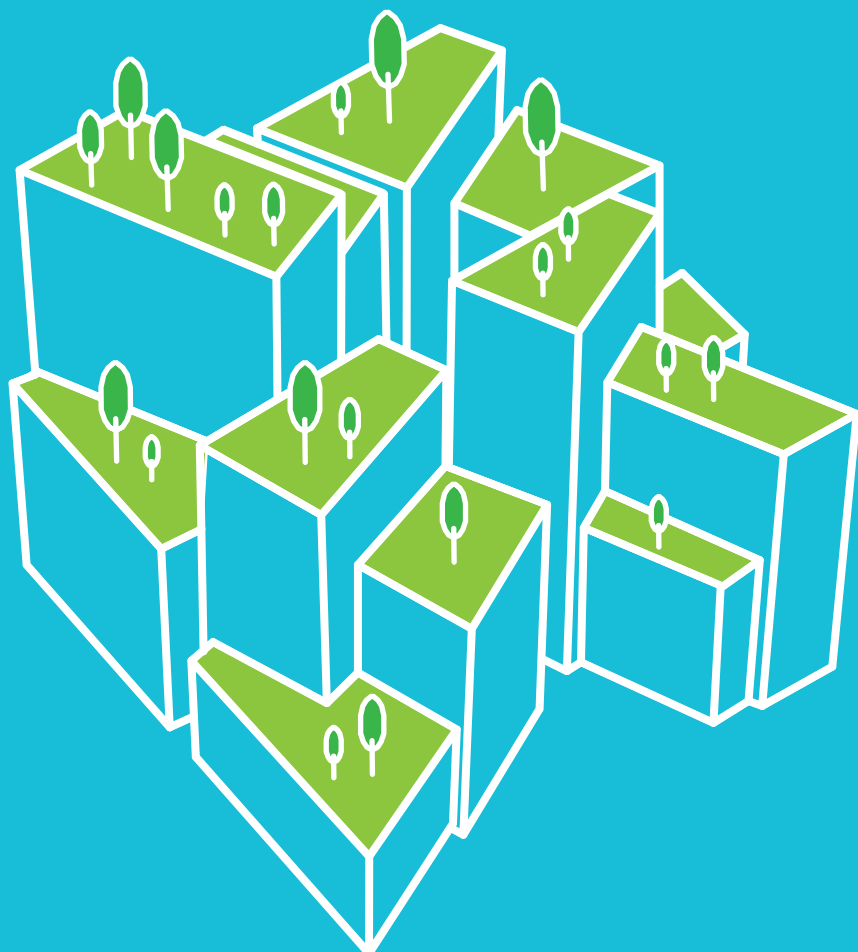


A Root Over Your Head: A Study of Green Roofs

KA

Katz Architecture
Project Management

305 7th Avenue, 20th Floor
New York, NY 10001

www.katzarch.com
212.353.1080

A traditional Scandinavian sod roof in Norway. Photo credit: Ximonic, Simo Rasanen, 2012.

by JULIA MACKENZIE
Architectural Associate

A green roof system is an extension of the existing roof which involves, at a minimum, high quality waterproofing, root repellent system, drainage system, filter cloth, a lightweight growing medium, and plants. (Greenroofs.org)

A BRIEF HISTORY

The Hanging Gardens of Babylon are considered to be one of the oldest known examples of using vegetation on roofs. Said to have been constructed around 500 BC, they made use of a layer of tar and reeds as an early form of waterproofing. While the existence of these gardens remains a matter of debate, the imagery and descriptions resonate today when we speak of vegetative roofs.

Traditional sod roofs of Scandinavia used a similar concept of rooftop greenery as a form of insulation, stormwater management and aesthetic improvement. Sod roofs were seen all over Scandinavia throughout the Middle Ages.

> Not only do green roofs help to cool down our cities, they also work to **improve the air quality within them**

Germany is considered to be the birthplace of modern-day green roof systems. The German oil crisis in the 1970s led to a nationwide shortage of fuel, so it became crucial to reduce reliance on HVAC equipment and the huge amounts of energy required to run it. Green roof requirements that came into practice at that time were proven to help insulate buildings and therefore lessen the heating and cooling loads within. The model developed then is nearly the same as the system used today, and Germany has continued to lead the way in green roof design ever since.

THE CASE FOR CONTEMPORARY GREEN ROOFS

In urban areas, rooftops account for 20-25% of horizontal surfaces. With so much otherwise unused space sitting nearly vacant, there is tremendous potential for positive development. Appropriately, these urban areas also tend to have the biggest need for sustainable interventions. The Urban Heat Island (UHI) effect describes the phenomenon where urban areas experience higher temperatures than surrounding non-urban areas. The surfaces created by cities, including streets, sidewalks and buildings absorb much more heat than natural surfaces formed from greenery. The added activity from higher populations, cars and infrastructure also generates more heat. UHI contributes to global warming and worsens both air and water quality. It also adds unnecessary additional strain to HVAC systems. All such symptoms of UHI can be substantially mitigated through the installation of green roofs.

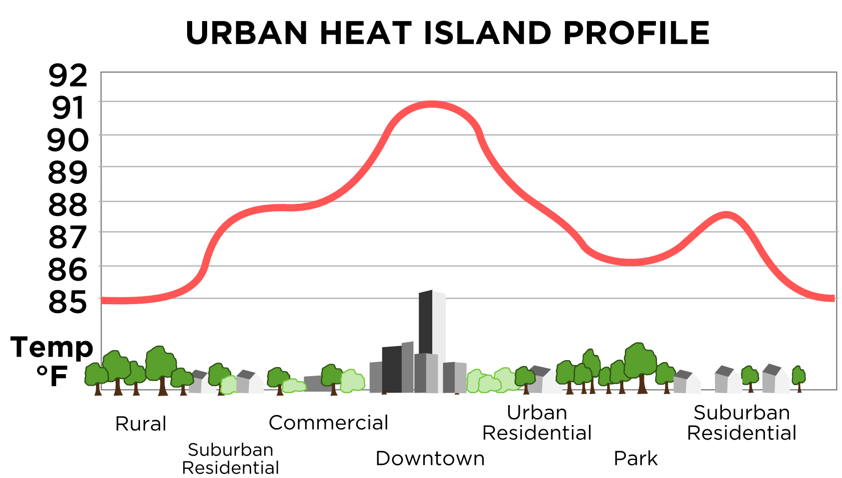


Image credit: NOAA

Not only do green roofs help to cool down our cities, they also work to improve the air quality within them. Vegetation captures airborne pollutants, filters noxious gasses, and cleans the air through plant respiration. Buildings fitted out with green roof

> "Using less energy also means there is less of a pull on power plants and therefore **natural resources**

systems decrease HVAC equipment use. Using less heat and air conditioning saves money over the years. Using less energy also means there is less drain on power plants and the natural resources they depend on to operate. From the perspective of waste diversion, HVAC equipment lasts longer if it is used less. Roofing membranes will also have longer lifespans if included in a green roof assembly. These changes are not inconsequential when looking at how much waste is produced in big cities annually.

Vegetative roofs have a positive impact on stormwater management. Municipal stormwater systems can become supercharged during heavy rainfall due to the large number of impervious surfaces in an urban environment. When this happens, the systems can flood and cause damage. When a building has a green roof installed, it is able to actively aid the stormwater system rather than overwhelm it. The moisture-retention layers in the roof assembly store water for plant use, thus reducing and slowing the flow of water directed to drains. Green roofs are able to retain 70-90% of the precipitation that falls on them in the summer months, and 24-40% in the winter months. Green roofs also work to regulate the temperature of stormwater, and serve as a natural filter for the runoff. All such features make these roofs an important part of a well-designed city.

> "Green roofs also work to regulate the temperature of stormwater, and serve as a **natural filter for the runoff**

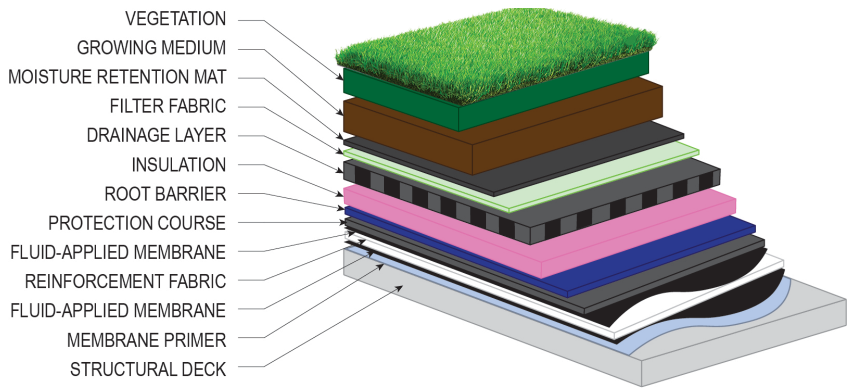
Perhaps one of the most obvious benefits of vegetative roofs is the aesthetic value they contribute to a building. Green roofs have the potential to offer some much-needed green space to the urban environment, thereby increasing the overall emotional well-being of a city's inhabitants. Vegetative roofs also work to absorb soundwaves, thus serving as a form of acoustic insulation for the building as well. If used throughout a city, green roofs could have an effect on the city's overall noise levels, further improving quality of life at a larger scale.

SYSTEM COMPONENTS

There are three main types of vegetative roofs. The first type, called extensive, has a growth medium depth of two to six inches and a weight of 12 pounds per square foot (psf). The second, called semi-intensive, has a growth medium depth of six to ten inches and a weight of 40psf. The third is called intensive, and has a growth medium depth of ten inches or greater, and a weight of around 60psf. In all three types, the roofing assembly remains the same, however the top layers vary in depth and thickness. Such differences will help to determine the types of plants and flora that can be used, and thus the overall weight of the system and irrigation requirements.

The foundation of any vegetative roofing system is the structural deck of the building's roof, which supports the live and dead loads associated with the green roof assembly. The layer above is the roof membrane, which provides the waterproofing. This layer is made up of a number of sublayers, the first being the membrane

Graphic depiction of the components of a typical green roof system.



primer, which is used to create a clean surface to build off of, rendering loose dust and dirt innocuous. After the primer comes the fluid-applied membrane, followed by the reinforcement fabric, and another layer of fluid-applied membrane. Once the fluid of the membrane dries, the three layers together encapsulate the reinforcement fabric within and create a monolithic system. The final element of the roof membrane is the protection course. This layer protects the membrane from UV damage, and allows for foot traffic. With all of these layers in place, the roof membrane is complete and ready for the green roof-specific elements.

The first layer above the roofing membrane is the root barrier. This layer is vapor impermeable, and prevents roots from potentially reaching and damaging the membrane below. The root barrier is typically loose laid, and the various panels must overlap by at least 12" to prevent any breaches. The next layer in the system is the insulation. Extruded Polystyrene (XPS) insulation is recommended in this assembly for its water resistance. The use of insulation above the roof membrane is referred to as an inverted roof membrane system (IRMA), and in this application, serves as a key detail for the protection and longevity of the vegetative roof system.

The layer that sits atop the insulation is the drainage layer, which can come in a number of different formats. Two examples include modular panels with channels beneath, and specially designed granular, gravel-like material. Standing water is the enemy of any roofing system, especially when there is a potential for root rot and the destruction of a living system. The drainage layer promotes water flow away from the roots towards the roof drainage system.

Green roof in Culemborg, The Netherlands. Image Credit: Lamiot.

The layer above the drainage layer is the filter fabric and/or moisture retention mat. This can be one or two layers, depending on the product selected. These layers help to provide some moisture at the roots of the plants, and also serve as the first line of defense in holding back the roots and keeping fine particles away from the insulation and drainage systems.

After the proper layering of all the appropriate membranes, insulation and mats outlined above, the growing medium can be installed. Growing medium is a special product, not quite a dirt or soil, but rather developed specifically for use in green roofs. The medium is designed so it does not become overly heavy when saturated with water, however not so light that it is easily picked up by the wind.

The vegetation is the last layer of a green roof system. Depending on the green roof type, it can vary from sedums to bushes to trees. Vegetation can be annual or biennial, changing from season to season, or something with less maintenance that can be planted and virtually ignored. Depending on the desired look and realistic upkeep regimen for the building, there is a type and style of vegetation for each application.

When it comes to determining all of the various requirements for green roof design and implementation, the gold standard of codes is the German Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL) Guidelines. These guidelines help to determine the growing medium makeup for a given climate, considering the mineral content, organic content, frost resistance, water permeability, water storage capacity, pH level, and other factors. This guide provides all information required for the planning, installation and maintenance of green roofs, and it is frequently updated with new findings and industry advancements.

INSTALLATION CONSIDERATIONS

The structural needs of a vegetative roof are greater than those of a typical roof assembly. The weight of the roof system, the type of vegetation, as well as the predicted level of water retention must be calculated when determining the building's structure, or whether an existing structure can handle the load. Wind loads

Green roof in Queenstown, Singapore.

must also be considered as they can be quite strong, especially on taller buildings. For this reason, the system should be designed to start slightly back from the perimeter of the roof, where wind loads are at their strongest. A path of pavers at the edges can

"Green roofs are considered to be great at **fire mitigation**

"Our proposal included a restoration of the façade, but also the addition of an elevator which required a bulkhead on the roof, **which had the community up in arms. The LPC allowed us to continue, but not without a fight**

work as a buffer, and help to lessen the intense pressure, and thus protect the greenery. In areas where winds are stronger, a wider perimeter may be advisable.

Fire resistance requirements for green roofs are generally the same as they are for any roof assembly. The designer will need to consult with local building codes to ensure the system and components all comply with required fire protection standards. Fortunately, one of the benefits of green roofs is their ability to mitigate fire spread. A properly designed green roof with appropriate plants and growing media will retain adequate moisture to achieve fire resistance benefits.

A key component of any roofing system, especially those which incorporate an active irrigation system, is the waterproofing. The waterproofing must be designed, installed, and maintained to appropriate standards to ensure the protection and longevity of the building and its components. In order to ensure that a system is truly watertight, a number of tests can be performed, such as a flood test or Electric Field Vector Mapping (EVFM) to ensure there are no breaches in the waterproofing membrane.

MAINTENANCE REQUIREMENTS

The specific maintenance requirements and methods for performing such work depends on the type of vegetative roofing system employed. For instance, extensive systems can be walked on during maintenance, and only require occasional weeding and annual fertilizing. Once these systems have been established, they generally do not need to be watered, as these plants can thrive off of rainfall alone.

When using an intensive system, the plants tend to be less resilient if trampled, so paths and walkways must be incorporated for maintenance purposes. Intensive systems will require weeding, trimming and fertilizing every few months, and irrigation systems are often encouraged, depending on the scale of the site and the site's climate. Semi-intensive systems sit somewhere in the middle in terms of their needs, but are slightly more akin to an intensive system. If properly maintained, a green roof can last 40 years, and will significantly extend the lifespan of a standard roof. Regardless of the green roof type and design, outlay is minimal when considered against the slew of traceable benefits.

A GREENER FUTURE

As technology develops, so too does the potential for innovation in the world of sustainable design. Certain factors that once limited the capabilities of a green roof are now being studied and reassessed. For instance, the pitch of a roof was once seen as an important feature for determining whether or not a vegetative system would work. For decades, it was believed that only "flat" roofs were appropriate for such systems. Fortunately, companies around the globe have begun to develop systems for roofs with 40%-70% slopes. Steeper roofs are possible as well, but require custom systems. With such technology, there are far fewer limitations to installing green roofs on new and existing structures alike.

View of Manhattan from a green roof. Image credit to Graham Hill

Moving beyond the horizontal and angled applications of greenery, applying the concept of a green roof on a vertical surface can be equally beneficial to a building. Façade greenery can serve as insulation, manage acoustic absorption, serve as a mechanism for shading, and clean the air, among many other benefits. Such installations have begun popping up across the globe, and tend to garner much enthusiasm for their aesthetics and sense of novelty.

As we look to the future of architecture and sustainability and their ever-complex relationship, it's important to focus on the ways in which the two can become more harmonious. More and more cities are adopting local laws and writing up regulations for

"As technology develops, so does the potential for innovation in the world of **sustainable design**

implementing green space. Copenhagen, Denmark, for instance, now requires all new buildings with roof slopes of less than 30% to have green roofs. New York City is moving in the same direction and has adopted a similar mandate with Local Laws 92 & 94. These laws require solar panels or green roofs on all new construction as well as on buildings undertaking major roof renovations.

As architects, we are proud to be on the forefront of the construction and development of our built world, as well as its sustainability and wellbeing for years to come. As an integral part of this joint goal, it is important for all of us to implement these systems, and appreciate the myriad of benefits and promising future they propose.

About the Author

Julia MacKenzie, a graduate of the University of Pennsylvania, has worked as an Architectural Associate at Katz Architecture since 2017. While primarily focused on the design and project management of residential and retail jobs in the office, she has always held an interest in greenspace and its integration into the urban fabric. Check out her other paper on Urban Greenspace in the Post-Pandemic Architecture series at: https://www.katzarch.com/resources.

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info@katzarch.com

Katz Architecture
Project Management

305 7th Avenue, 20th Floor
New York, NY 10001

www.katzarch.com
212.353.1080