Modern appeal. *This roof atop a home designed by Jonathan Feldman (www.feldmanarchitecture.com) demonstrates how living roofs can fit contemporary lifestyles and structures.*

An Inside Look at Living Roofs

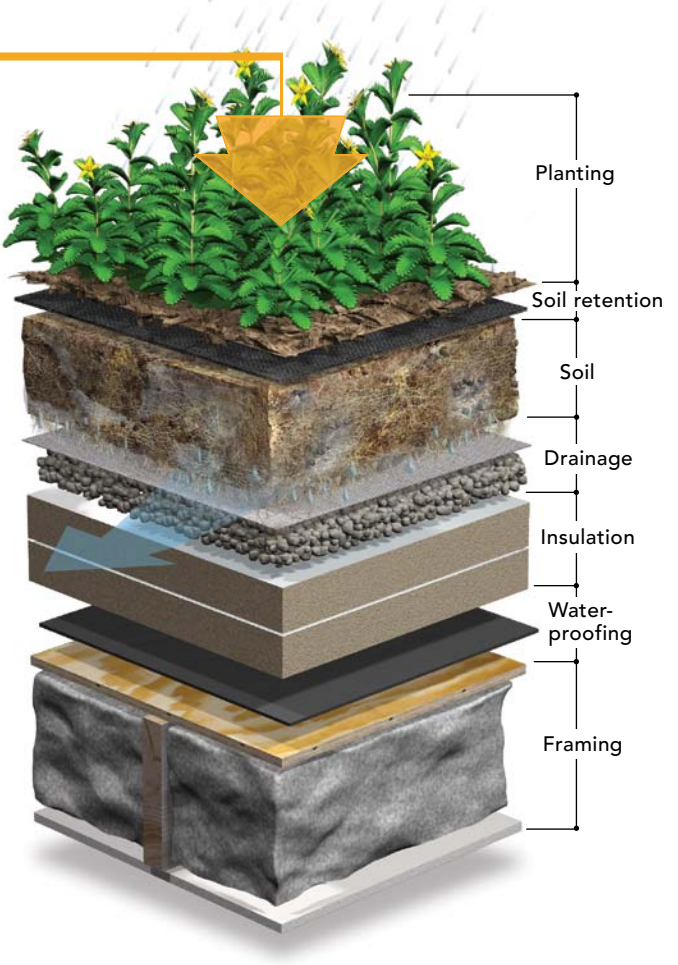
If you follow this approach toward energy savings, storm-water control, and progressive design, you had better get the details right

BY ROXI THOREN

Photo: Joe Fletcher Photography

THE LAYERS OF A LIVING ROOF

There are different ways to construct a living roof. However, built-in-place roofs like the one shown here are typically composed of the same elements. Failure to understand or failure to install any of the layers correctly means you'll likely end up with a roof that falls short on aesthetics and performance. A living roof is a system, with each layer complementing the other.



For anyone who has fought moss growing on a shady roof, the idea of intentionally planting a living roof may seem odd, but living roofs make a lot of sense on many homes. A living roof, also referred to as a vegetative or green roof, is a layer of soil and plants installed over a waterproof roof system. There is a long-standing history of living-roof performance that should help to put skeptics at ease. For example, turf houses in Scandinavia have used thick layers of soil and grass to insulate wood-framed homes for centuries. Contemporary living roofs, developed mostly in Germany beginning in the 1970s, also have a successful history. Germany has had living-roof standards since 1995, and some living roofs there have been in service for more than 30 years. Studies on those roofs have shown that they provide a number of economic, aesthetic, and environmental benefits when designed and built properly.

The energy factor

For many, interest in living roofs is based in part on their aesthetic appeal and in part on their environmental benefits. But the decision to install a roof that can cost

$10 to $40 per sq. ft., depending on soil depth and roof design, should also be influenced by the economic and energy-related benefits.

The most direct benefit of a living roof is a potential reduction in annual residential heating and cooling costs. Living roofs act as an additional layer of insulation on top of a house. Their insulating impact on home energy consumption isn't universal, however. Living roofs provide higher energy savings in summer than in winter, making them particularly useful in hot regions of the country. During the summer, plants shade the soil, and the soil absorbs moisture, which helps to reduce solar-heat gain in the home and reduces cooling needs by up to 25%. In the winter, soil and evergreen plants, which trap pockets of air, act as additional insulation. Plants also tumble air as it moves over the roof, reducing convective heat loss due to wind. While the benefits of a living roof are less dramatic in winter than they are in summer, studies have shown that living roofs can reduce wintertime energy use in the top floors of a house by up to 12%. While the energy-related attributes of a living roof in a heating-dominated climate may not be of primary significance, there are other benefits to consider as well.

Benefits beyond the house

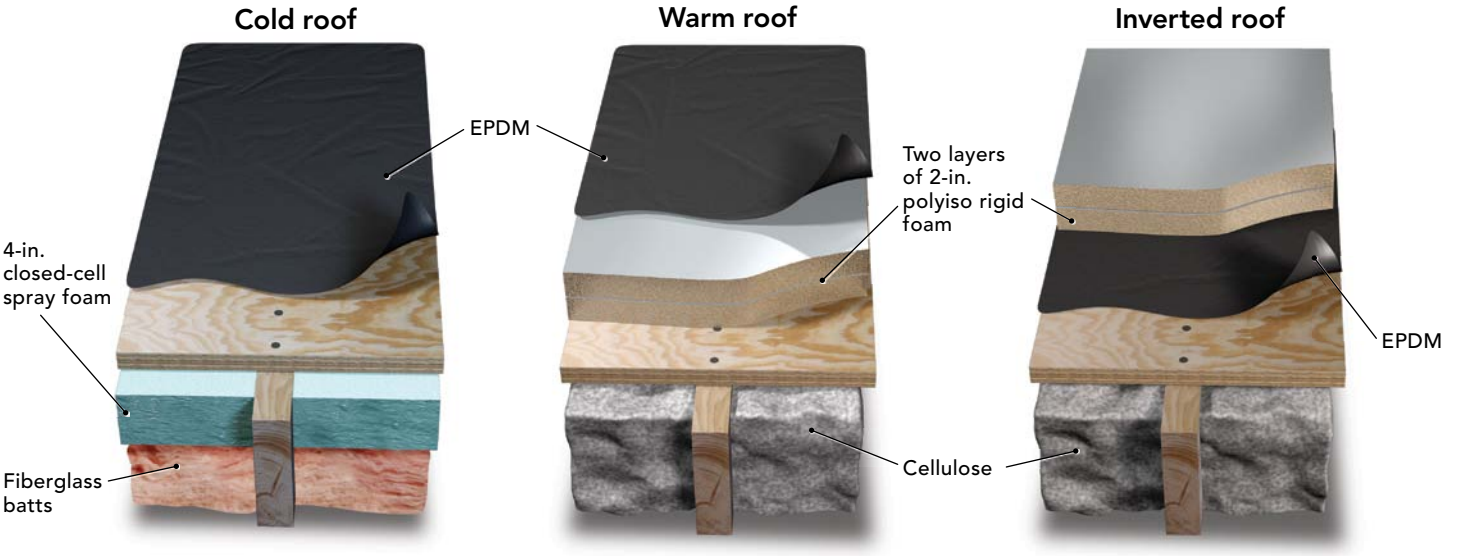
Living roofs last a long time and reduce the impact of individual homes on their surrounding sites and communities at large. The soil and growth medium on a living roof nearly doubles the life of the roofing material below it. The roof is protected from sunlight, which degrades most roofing materials, and from physical damage due to falling branches or wind-borne debris.

Living roofs also provide a number of environmental benefits, which translate into economic benefits in some parts of the country. The plants on the roof filter air pollutants, improve air quality, and buffer homes from noise—an attractive quality to homeowners in urban areas. Living roofs also help to reduce the heat-island effect in dense communities (see "How It Works" in *FHB* #218).

Most significantly, living roofs retain rainfall and slow, filter, and cool any storm

WATERPROOFING AND INSULATION

Single-ply sheet waterproofing membranes, such as PVC or EPDM, are the most common products used on living roofs. These membranes are impervious to water and serve as a natural root barrier. The only drawback to this approach is that single-ply sheet membranes have seams when installed, which is a weak point in terms of leakage and as a root barrier. Rigid insulation, sheet drainage, or an additional layer of polyethylene root barrier applied over the seams can help to solve this problem. A less common but better-performing waterproofing layer is achieved with fluid-applied membranes, which are typically made with urethane or bitumen. These materials create a durable, seamless surface that will not be breached by water or roots. This type of membrane performs like a vapor retarder, much like synthetic roof underlayment.



The three ways to insulate the roof are equally effective. In general, the best option is not to vent the roof deck and to control the temperature of the condensing surface—the roof sheathing—with air-impermeable rigid- or spray-foam insulation. The labels applied to living-roof assemblies shouldn't be confused with those of conventional roofs. For example, typically a cold roof is a roof with vented sheathing. In living-roof construction, it simply means that all the insulation is below the roof deck. A warm roof has additional rigid insulation placed between the roof deck and the waterproofing layer. An inverted roof has rigid insulation placed above the waterproofing layer. The benefit of this approach is that the insulation protects the waterproofing layer from damage. The amount of spray-foam or rigid insulation is based on the R-values in table R806.4 of the International Residential Code. The insulation keeps the roof sheathing warm enough throughout the year to prevent condensation. The amount of bulk insulation installed is based on the desired R-value of the roof, which is typically around R-40.

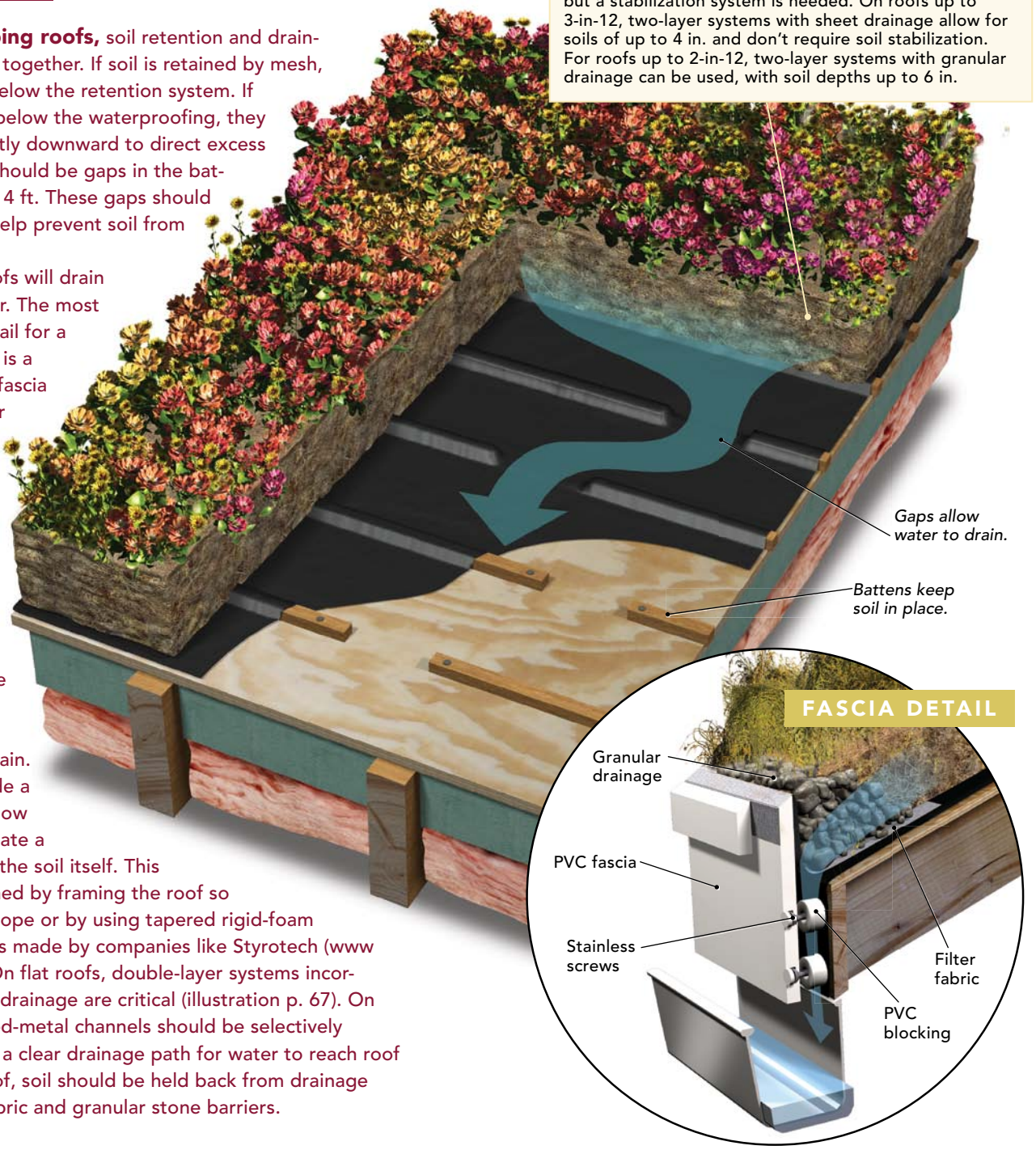
DRAINAGE

On steeply sloping roofs, soil retention and drainage need to work together. If soil is retained by mesh, drainage occurs below the retention system. If battens are used below the waterproofing, they should slope slightly downward to direct excess water, and there should be gaps in the battens every 3 ft. to 4 ft. These gaps should be staggered to help prevent soil from washing away.

Most sloped roofs will drain directly to a gutter. The most common eave detail for a continuous gutter is a gap between the fascia and roof with filter fabric used to retain the soil. Alternatively, you can use a perforated or slotted-metal drip edge specifically designed for living roofs.

Although they're less common, flat roofs also need to be designed to drain. It is best to provide a very low slope below the soil and to create a level surface with the soil itself. This is best accomplished by framing the roof so that it has a low slope or by using tapered rigid-foam sheathing, which is made by companies like Styrotech (www.styrotech.com). On flat roofs, double-layer systems incorporating granular drainage are critical (illustration p. 67). On these roofs, slotted-metal channels should be selectively placed to provide a clear drainage path for water to reach roof drains. On any roof, soil should be held back from drainage exits with filter fabric and granular stone barriers.

Roof slope impacts roof design. On roofs up to 7-in-12, 3 in. of soil works best. Plant roots help to stabilize soil, but a stabilization system is needed. On roofs up to 3-in-12, two-layer systems with sheet drainage allow for soils of up to 4 in. and don't require soil stabilization. For roofs up to 2-in-12, two-layer systems with granular drainage can be used, with soil depths up to 6 in.



water that leaves the roofs. Typically, in heavily developed areas, rainwater is quickly piped from roofs, roads, driveways, parking lots, and sidewalks into streams and rivers. This runoff is hotter, dirtier, and faster moving than rainwater falling on undeveloped land, which tends to absorb water rather than direct it. To encourage a reduction in erosion and pollution resulting from stormwater runoff, some municipalities have lowered or completely eliminated wastewater-system fees for residential projects that retain some or all of their storm water on site.

Roof designs vary

Almost any home is a good candidate for a living roof, but no single approach suits all applications. There are two basic types of living roofs: single layer and double layer. Single-layer roofs have only a thin layer of soil above the waterproofing layer (illustration above). The soil is specified both to retain some water and to drain well. These systems are best on sloped roofs and on low-maintenance roofs where plant choice is less critical.

Double-layer roofs have a drainage layer and a soil layer above the waterproof roof deck, separated by filter fabric to prevent the soil from clogging the drainage layer. Double-layer roofs are best for low-slope and flat roofs, for accessible roofs intended as gardens, and for roofs whose owners want a large variety of plant options.

Modular products save time

As living roofs have grown in popularity, a number of modular products have appeared on the market. These products typically include plants, so they appear lush on installation and are faster to install than custom, built-in-place roofs. They also have engineered soils, which takes the guesswork out of specifying soil composition and plant type. Also, roof repairs are easier, as a module can be removed to provide access to the roof below.

Modular products are a good option for those less concerned with plant choice. They come in three basic forms, each with its own benefits and drawbacks.

GRIDS These systems of low boxes, usually made of plastic or metal and often with integrated drainage, are best suited for low-slope roofs. They come filled with soil and plants. While these modules can provide quick access to the roof below and are relatively easy to install, some argue they don't yield the same storm-water-management benefits of other approaches. Also, the gaps between trays can leave the waterproofing layer exposed to damage from sunlight and can enable tree seedlings and other plants to take root on the waterproofing layer.

Cost: $18 to $20 per sq. ft. (Green Roof Blocks, photo left)

Sources
GreenGrid: www.greengridroofs.com
Green Roof Blocks: www.greenroofblocks.com
GreenTech: www.greentechitm.com

TILES Tiles are comprised of a base layer made of drainage material that is covered with a thin layer of soil and plants. Similar to modules in grid form, tiles can be installed quickly and provide instant visual appeal. While the work is fast, it still demands care, as improperly handled tiles can easily lead to loss of growth medium and plant damage. Tiles are best used on low-slope roofs. They can be used on steeper roofs, but above a 3-in-12 pitch, they demand a retention system.

Cost: $9.75 per sq. ft. (Sedum Master, photo left)

Sources
Hydrotech InstaGreen Tile: www.hydrotechusa.com
Sedum Master: www.sedummaster.com

MATS Mats are similar to sod, only instead of turf, the plant choice is typically succulents. They are usually 4 ft. wide and up to 7 ft. long. They install quickly and have a more uniform appearance than grids or tiles. Similar to tiles, mats can be used anywhere, but they need a retention system on roofs steeper than 3-in-12. Newly installed mats need proper irrigation. Otherwise, they can dry out, and plants can become damaged. If severely neglected, new mats can shrink and expose the waterproofing layer, making it susceptible to damage.

Cost: $20 to $25 per sq. ft. (InstaGreen Carpet, photo left)

Sources
Etera: www.etera.com
Hydrotech InstaGreen Carpet: www.hydrotechusa.com
Xero Flor America: www.xeroflora.com

Within these categories there is a lot of room for customization, so the owner, the designer, and the contractor need to work together to determine what purpose the roof will serve. The intent of the roof should be the driving force behind its overall design.

Engineered roof framing is common, but not a must

Living roofs can weigh a lot; therefore, they demand more support than conventional roofs can provide—sometimes. The general rule of thumb is that for every inch of saturated soil depth, a living roof weighs approximately 7 lb. per sq. ft. (psf). A living roof that is 3 in. deep, for example, weighs about 21 psf after a rainstorm. If the roof will be used by residents as a rooftop garden, the roof structure also needs to support the live load of people and the dead load of paving or decking materials.

Most living roofs demand an amount of increased structural support, which should be determined by an engineer. As a general rule, however, thin living roofs that won't be used as living space—up to a maximum soil depth of 5 in.—can be supported by standard residential-construction specifications.

Retrofitting existing roofs is more complicated, and typically only soil depths of 3 in. to 4 in. should be specified. No matter the extent of your project, it's always wise to consult an engineer well before the construction phase.

Maintenance is limited

Maintenance falls into two categories: roof maintenance and garden maintenance. The roof itself should be monitored to ensure that it is draining properly.

Garden maintenance can be as time-consuming as the owner wants. In general, the roof needs to be weeded as necessary, flowers need to be trimmed seasonally, and the roof needs to be fertilized every two years—especially if its soil depth is thin. All living roofs require some watering in the first two years as the plants grow their roots. With proper plant choice, roofs then need no watering except perhaps in instances of extreme drought. Even so, it's best to let gardens go dormant during those periods instead of taxing local water sources. □

Roxi Thoren is an assistant professor in the departments of architecture and landscape architecture at the University of Oregon. Drawings by Don Foley.

Photos: top, courtesy of Green Roof Blocks; center, courtesy of Sedum Master; bottom, courtesy of American Hydrotech.