Green Roof Technology

INOGATE Programme
New ITS Project, Ad Hoc Expert Facility (AHEF)
Senior Task Coordinator AM-55 Larry Good, CEM, CEA

Slides prepared by: Albin Zsebik, PhD, CEM
What is a Green Roof?

A green roof or living roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane.

It may also include additional layers such as a root barrier and drainage and irrigation systems. Container gardens on roofs, where plants are maintained in pots, are not generally considered to be true green roofs, although this is debated. Rooftop ponds are another form of green roofs which are used to treat greywater.
Green Roofs have been around for a very long time. The first green roofs we know of were used on temples in ancient Mesopotamia (fourth millennium). Vikings also used green roofs to protect houses from harsh weather.
More recently, Europe has adopted green roofs to improve quality of urban environments. Europeans have done a great deal of research to improve green roof technologies, focusing on root repellant, waterproofing membranes, drainage systems, lightweight growing media and drought tolerant plants.
From Past to the Future

Building in Norway

The SOLANOVA Building

Source Wikipedia
What is a Green Roof?

Green roofs serve several purposes for a building, such as absorbing rainwater, providing insulation, creating a habitat for wildlife, and helping to lower urban air temperatures and mitigate the heat island effect.

There are two types of green roofs:

• **intensive roofs**, which are thicker and can support a wider variety of plants but are heavier and require more maintenance, and

• **extensive roofs**, which are covered in a light layer of vegetation and are lighter than an intensive green roof.
Environmental benefits:

1. Reduce heating (by adding mass and thermal resistance value)
   • Reduce cooling (by evaporative cooling) loads on a building during the summer
   • Natural Habitat Creation
   • Filter pollutants and carbon dioxide out of the air which helps lower disease rates such as asthma
   • Filter pollutants and heavy metals out of rainwater
   • Help to insulate a building for sound; (the soil helps to block lower frequencies and the plants block higher frequencies)
   • If installed correctly many living roofs can contribute to LEED points
   • Increase agricultural space
   • With green roofs, water is stored by the substrate and then taken up by the plants from where it is returned to the atmosphere through transpiration and evaporation.
   • Green roofs not only retain rainwater, but also moderate the temperature of the water and act as natural filters for any of the water that happens to run off.
Financial benefits:

1. Increase roof life span dramatically, for example a green roof protects the waterproofing membrane, particularly from UV light, increasing the life expectancy.

2. Increase real estate value

3. Reduction in energy usage

4. In some countries tax incentives - for example, a one-year property tax credit is available in New York City, since 2009, for property owners who green at least 50% of their roof area.

A green roof is often a key component of an autonomous building - a building designed to be operated independently from infrastructural support services such as the electric power grid, gas grid, municipal water systems, sewage treatment systems.
Disadvantages:

The main disadvantage of green roofs is
1. the higher initial cost of the building structure,
2. waterproofing systems and
3. root barriers.

The additional mass of the soil substrate and retained water can require additional structural support.

Some types of green roofs do have more demanding structural standards especially in seismic regions of the world.

Some existing buildings cannot be retrofitted with certain kinds of green roof because of the weight load of the substrate and vegetation exceeds permitted static loading.

Depending on what kind of green roof it is, the maintenance costs could be higher, but some types of green roof have little or no ongoing cost.
BUILT-UP - A built-up green roof system consists of different layers that will be laid down on site, one after the other in the following order: Root barrier, drainage, filter, growing media, plants.

DEAD LOAD - The intrinsic, invariable weight of a structure, such as a roof. It may also include any permanent loads attached to the structure. The dead load of a green roof is the fully saturated weight of the system.

DRAINAGE LAYER - Part of the standard green roof which allows excess water to drain away to the roof drains. Some drainage layers also provide a reservoir to retain moisture for a longer period and increase drought tolerance of the plants. Drainage layers are made of a variety of materials including hard plastic, recycled materials, foam or lightweight aggregates.
Glossary 2.

**Extensive Green Roof** - Low nutrient and low maintenance, often designed to be light weight. Not irrigated. Usually shallow substrate, typically less than 4”, and often vegetated with sedum and drought tolerant perennials.

**Filter Fabric** - Part of a standard green roof which prevents fines and sediments from being washed into the roof drains.

**Flashings** - Pieces of sheet metal or waterproofing membrane used to cover and protect certain joints and angles, such as where a roof comes in contact with a wall or chimney. Protects against leakage. Flashings are a sensitive part in the waterproofing system.

**Growing media/Substrate** - An engineered soil specifically blended for green roof plants. It allows water to be absorbed and to drain away, insuring plant survival. Substrates contain specified ratio of organic and inorganic material.
**Glossary 3.**

**Intensive Green Roof** - A green roof that requires intensive maintenance. Usually irrigated and with more than 8” depth of growing media. Equivalent to a garden and usually referred to as a “garden roof”.

**Live Load** - Live loads are the loads produced by the use and occupancy of the building. They do not include construction or environmental loads such as wind load, snow load, rain load, earthquake load, flood load, or dead load. Live loads on a roof are those produced during maintenance by workers, equipment, and materials, and during the life of the structure by people or objects.

**Parapet** - Low protective wall or barrier at the edge of a roof.
Glossary 4.

**Perennials** - Plant having a life cycle lasting more than two years.

**Peak flow reduction** - Decrease of the volume rate discharge released after a rain event.

**Protection fabric** - Geotextile blanket that provides protection to the waterproof membrane.

**Root barrier** - A layer designed to prevent roots from penetrating the waterproofing layer and building envelope.
**Sedums** - A genus of about 400 species of low growing leafy succulents which are drought tolerant and found throughout the Northern hemisphere. Not all species are suitable for roofs. Sedums, for the most part, are CAM (crassulacean acid metabolism), as an adaptation for arid conditions. CO2 enters the stomata during the night to be converted in organic acids. During the day stomata are closed, which prevents the plant from drying.

**Semi Intensive Green Roof** - Intermediate green roof type with characteristics of both extensive and intensive green roofs. Typically 4” to 8” growing media depth, sometimes irrigated and usually planted with a wide range of species. The maintenance is higher than an extensive green roof.

**Vegetation free zone** - Space left without vegetation and filled usually with stone ballast or pavers.
Green Roof components

Vegetation (sedums)
Growing Media
Filter Fabric
Drainage
Protection Fabric
Root Barrier
Waterproofing Membrane
Roof Deck

*If the waterproofing membrane doesn't include it

Source: http://www.vegetalid.us/green-roof-systems/green-roof-101/what-is-a-green-roof
Plants that can be found on Extensive Green roofs

• Succulent (sedum type) Chive green roof
• Perennials and Bulbs (iris, carnation, ...)
• Grasses (fescue, ...)
• Small woody (lavender, ...)

For all vegetated roofs, plant varieties should be selected and adapted to the particular climate, keeping in mind that conditions on roofs are more severe than on the ground.
Growing Media

Growing media is an engineered soil specifically blended for green roof plants. It allows water to be absorbed and to drain away insuring plant survival. Substrates contain specified ratio of organic and inorganic material.
Filter Fabric

Green Roof layer which prevents soil and sediments from being washed into the roof drains.

Drainage

Drainage allows excess water to drain away to the roof drains. Some drainage layers also provide a reservoir to retain moisture for a longer period and increase drought tolerance of the plants.

Drainage layers may be made of a variety of materials including hard plastic, recycled materials, foam or lightweight aggregates.
Three methods available to establish the plants:

<table>
<thead>
<tr>
<th>Planting method</th>
<th>Implementation Season</th>
<th>Initial foliage coverage</th>
<th>Foliage coverage after 1 year</th>
<th>Foliage coverage after 3 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-vegetated systems (sedum mats, trays fully grown)</td>
<td>All year long above freezing temperature</td>
<td>&gt; 80%</td>
<td>&gt; 80%</td>
<td>&gt; 80%</td>
</tr>
<tr>
<td>Plugs</td>
<td>Spring and Fall</td>
<td>5%</td>
<td>60%</td>
<td>&gt; 80%</td>
</tr>
<tr>
<td>Cuttings or seeding</td>
<td>Mid Spring and Early Fall</td>
<td>0%</td>
<td>40%</td>
<td>&gt; 80%</td>
</tr>
</tbody>
</table>
Plants on a roof don’t look the same all year long

They flower, they grow, they go dormant, their colors change. In the winter they often look red.
Green Roof Types:

Green roofs can be categorized as intensive, semi-intensive, or extensive, depending on the depth of planting medium and the amount of maintenance they need.

**Extensive green roofs** traditionally support 10-25 pounds of vegetation per square foot, while **intensive roofs** support 80-150 pounds of vegetation per square foot.
Green roofs are divided into three different sections depending on building constraints and design intent. 

Green Roof types (or categories):

<table>
<thead>
<tr>
<th>Intensive</th>
<th>Semi – Intensive</th>
<th>Extensive</th>
</tr>
</thead>
<tbody>
<tr>
<td>The aim is to provide a real ‘landscape’ on the roof</td>
<td>The aim is to provide an aesthetic effect</td>
<td>The aim is to combine roof performances and low maintenance</td>
</tr>
<tr>
<td>Usually more than 6” of growing media depth</td>
<td>Around 6” of growing media depth</td>
<td>3” to 6” of growing media</td>
</tr>
<tr>
<td>Often accessible</td>
<td>Often partially accessible</td>
<td>Often not accessible</td>
</tr>
<tr>
<td>Wide plant diversity</td>
<td>Great plant diversity</td>
<td>Low plant diversity (sedums, bulbs, perennials)</td>
</tr>
<tr>
<td>High Maintenance</td>
<td>Maintenance is important</td>
<td>Low Maintenance</td>
</tr>
<tr>
<td>Always irrigated</td>
<td>Often irrigated</td>
<td>No irrigation</td>
</tr>
</tbody>
</table>
Advantages of Each Categories

**Intensive**
- Aesthetic
- Plant diversity
- Range of design

**Semi – Intensive**
- Combines benefits from Intensive and Extensive

**Extensive**
- Lightweight
- Suitable for large areas
- Low maintenance
- Best cost/benefits ratio
- Better for retrofit
- Low front cost $
- Easier to replace
**Green roof systems:**

Systems are related to the method of installing the green roof, three systems are available:

<table>
<thead>
<tr>
<th>Module System (Hydropack®)</th>
<th>Hybrid System</th>
<th>Built-up System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition</strong></td>
<td>All the Green roof layers are contained within one tray that can be removed anytime</td>
<td>Growing media and plants are contained within the tray and creates, once in place, a built-up system with no compartmentalization</td>
</tr>
<tr>
<td><strong>Lead Time</strong></td>
<td>2 week lead time</td>
<td>Usually 3 growing months</td>
</tr>
</tbody>
</table>
## Green roof systems:

<table>
<thead>
<tr>
<th>Vegetation coverage</th>
<th>Module System</th>
<th>Hybrid System</th>
<th>Built-up System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>95% minimum vegetation coverage the day of the installation</td>
<td>Cuttings and plugs: 80% coverage after 2 years Sedum mats: 90% coverage the day of the installation</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>No establishment maintenance needed. Regular maintenance will depend on aesthetic expectations</td>
<td><strong>Cuttings and plugs:</strong> Initially more maintenance for the establishment of the plants Sedum mats: no establishment maintenance needed. Will depend on aesthetic expectation</td>
<td></td>
</tr>
<tr>
<td>Cost for typical extensive system- in USA</td>
<td>$13-20 per sq. ft.</td>
<td>$16-25 per sq. ft.</td>
<td>$12-$15 per sq. ft.</td>
</tr>
</tbody>
</table>
Green roof systems:

<table>
<thead>
<tr>
<th></th>
<th>Module System</th>
<th>Hybrid System</th>
<th>Built-up System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterproofing</td>
<td>Any type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>Less design flexibility (ex: curves, irregular angles) square design</td>
<td>Complete design flexibility</td>
<td></td>
</tr>
<tr>
<td>Leak Detection</td>
<td>Same requirements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retrofit Roofs</td>
<td>Requires a brand new waterproofing membrane.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aesthetics</td>
<td>Will depend mostly on the maintenance, more than the system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant Health</td>
<td>Hydropack® allows water and nutrient circulation to keep healthy plants</td>
<td>They often allow water and nutrients circulation</td>
<td>water and nutrient circulation to keep healthy plants</td>
</tr>
</tbody>
</table>
# Green roof systems:

<table>
<thead>
<tr>
<th>module system</th>
<th>Hybrid System</th>
<th>Built-up System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Removal</strong></td>
<td>Easy removal for roof repairs and trays are put back in place after the repair</td>
<td>No easy removal</td>
</tr>
<tr>
<td><strong>Sloped Roofs</strong></td>
<td>Hydropack® can be installed on almost any slope. Recommended only with Hydropack®, proven by extended experience in Europe</td>
<td>Low to Light slope only</td>
</tr>
</tbody>
</table>

Functional layers of a typical extensive Green Roof

1. Roof deck, Insulation, Waterproofing
2. Protection- and Storage Layer
3. Drainage- and Capilarity Layer
4. Root permeable Filter Layer
5. Extensive Growing Media
6. Plants, Vegetation
Drainage layer

Water storage

- Rain water retention
- Water run-off delay
- Water supply for vegetation
Types of drainage

Granular

- Gravel
- Smashed stone
- Lava, tufa
- Expanded clay aggregate
- Smashed brick
- Industrial cinder

Plastic

- Form-foamed expanded PS
- Plastic plates
- PU or PE foam matress
Combined drainage
Water retention

<table>
<thead>
<tr>
<th>Layer thickness</th>
<th>Run-off coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 50 cm</td>
<td>C = 0,1</td>
</tr>
<tr>
<td>25-50 cm</td>
<td>C = 0,2</td>
</tr>
<tr>
<td>15-25 cm</td>
<td>C = 0,3</td>
</tr>
<tr>
<td>10-15 cm</td>
<td>C = 0,4</td>
</tr>
<tr>
<td>6-10 cm</td>
<td>C = 0,5</td>
</tr>
<tr>
<td>4-6 cm</td>
<td>C = 0,6</td>
</tr>
<tr>
<td>2-4 cm</td>
<td>C = 0,7</td>
</tr>
</tbody>
</table>
Run-off delay

Time difference between max amplitudes

In case of short period rain

Bare roof run-off

Green roof run-off
Heat attenuation
Heat attenuation

Terrace

Extensive green roof

\[ T_{\text{avg}} = 8.8 \, ^\circ\text{C} \]

\[ T_{\text{avg}} = -0.7 \, ^\circ\text{C} \]

F. Daniel Szlivka - Szent István University, Gödöllő, Hungary
Heat attenuation

Inside ceiling temperatures

Under terrace roof

Under green roof

\[ T_{\text{avg}} = 18 \, ^\circ\text{C} \]

\[ T_{\text{avg}} = 21.4 \, ^\circ\text{C} \]
# Heat attenuation

<table>
<thead>
<tr>
<th>Roof types</th>
<th>Summer heat loss (W/m²)</th>
<th>Winter heat loss (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bare flat roof</strong> (10 cm therm. insul.)</td>
<td>-11.1</td>
<td>12.9</td>
</tr>
<tr>
<td><strong>Duo roof</strong> (2×10 cm therm. insul.)</td>
<td>-7.38</td>
<td>8.61</td>
</tr>
<tr>
<td><strong>Extensive green roof</strong> (10 cm therm. insul. + 15 cm substrate)</td>
<td>-1.85</td>
<td>7.40</td>
</tr>
</tbody>
</table>
Can a green roof be installed in all climates?

Sedums and other hardy plants can be used for green roofs in various situations.

A personalized study should be conducted for each project, as it will allow the best plant and growing media to be chosen, and point out particular precautions for the installation, the maintenance and the irrigation.
Can an extensive green roof be walked on?

During the installation of the green roof it is acceptable to step on the vegetation to ease the process. It won’t hurt it as long as the plant mix is mainly sedums and you water shortly thereafter.

Construction activity post green roof installation is forbidden. The green roof must be installed last.

If you decide to develop access to your green roof, remove vegetative trays and replace them with deck pedestals.
Design Considerations

In order to assemble a vegetated roof for optimal performance, is taken many factors into consideration:

1. Budget
   • Wind
   • Climate
   • Exposure
   • Standards
   • Structural Loading Capacity
   • Design Intent
   • Irrigation system
   • Vegetation Free Zones
   • Roof environment considerations
   • Green roof layer: Growing Media
   • Green roof layer: Drainage system
   • Waterproofing Membrane Assembly
   • Slope applications
   • Safety
Design Considerations – Budget

The designer should take into the consideration the possibilities of investor.

For design information USA conditions

- Extensive green roof: $12-25$ per sq. ft.
- Semi-Intensive: $20-35$ per sq. ft.
- Intensive: $40$ and up per sq. ft.
Design Considerations – Wind

Green Roofs must be designed to resist anticipated wind loads in compliance with local building code requirements (ASCE 7).

It is recommended to follow the wind standard for green roofs: ANSI/SPRI RP-14 Wind Design Standard for Vegetative Roofing Systems.

It is recommended to design vegetation free zones filled with pavers or stone ballast at the perimeter (edge and corner zones) of the roof where the wind pressure is high.

Parapets will decrease wind pressure on the edges of the roof area.
The climate is an important factor in selecting the plants for a green roof.

The hardiness zone map geographically defines areas in which a plant can live according to the minimum temperature for the area. For example, sedum album is “hardy to zone 4”, which means that sedum album can withstand a minimum temperature of –30°F (-34°C).

Remember that a good plant list needs to combine a mix of groundcover plants as well as accent plants.
Design Considerations–Exposure

Sun exposure is a very important factor to take into account when designing a green roof because it will influence the plant selection.

To make sure you’re installing the best plants for your roof, we break down sun exposure into three categories: Full Sun; Sun/Shade and Shade.

Use the Plant Selection Tool to find the plants that will best fit your roof exposure.

Most of Sedums are not recommended for shade environments.
Design Considerations – Standards

**ASTM** - the American Society for Testing and Materials

**E2396—05**  Standard Test Method for Saturated Water Permability Granular Drainage Media

**E2397—05**  Standard Practice for Determination of Dead Loads and Live Loads

**E2398—05**  Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers

**E2399—05**  Standard Test Method for Maximum Media Density for Dead Load Analysis

**E2400—06**  Standard Guide for Selection, Installation and Maintenance of Plants

Free of charge downloadable -  [http://www.vegetalid.us/faq](http://www.vegetalid.us/faq)
Design Considerations – Standards

FM Global:
Approval Standard for Vegetative Roof Systems Property Loss Prevention Data Sheets GREEN ROOF SYSTEMS

ANSI - the American National Standards Institute
SPRI VF-1 External Fire Design Standard for Vegetative Roofs
SPRI RP-14 Wind Design Standard for Vegetative Roofing Systems

Downloadable from:
http://www.vegetalid.us/green-roofs/green-roof-101/design-considerations#/architecture-engineering-resources/green-roofs/design-considerations/standards
Design Considerations –
Structural Loading Capacity

Structural Loading Capacity is the most important factor and first step when designing a green roof as it will determine the type (extensive or intensive).

The building and roof deck must be able to support the added dead and live load of the green roof.

The introduction of a green roof may add live load if the roof is accessible and human traffic should be taken into account.

The dead load for a green roof is the system weight when fully saturated with water (ASTM E 2397).
Design Considerations - Design Intent

Vegetation biodiversity is influenced by the growing media depth (extensive or intensive types).

For extensive systems, plant choice depends on the design intent, the location and the budget.

Vegetation choice will have an impact on the upfront cost as well as long term maintenance.

It is unwise to design high end landscapes on a roof if the building Owner doesn’t have a budget for appropriate maintenance.

For each design intent has an optimal vegetated solution
Design Considerations – Irrigation system

When the vegetation is applied with cuttings, plugs or sedum mats, temporary irrigation is required until the vegetation is well established. Design intent will dramatically influence the implementation of a permanent irrigation system:

- Using non-drought tolerant plants or native plants will generally require a permanent irrigation system.
- For heat island reduction intent, an irrigation system will be recommended to increase the evapotranspiration of the plants and cool down the temperature.
- For highly visible green roofs, irrigation is recommended to increase the aesthetic quality of the plants.

When designing a green roof, there should always be water access on the roof to hook-up during drought periods.
A Vegetation Free Zone is the space left around the perimeter of the green roof and around rooftop equipment without vegetation and usually filled with stone ballast or pavers.

These zones are between 12” and 24” wide. They are recommended to ease the visual inspection and limit the growth of the vegetation into the drains.
Design Considerations –

Roof environment considerations

- When windows or walls are reflecting on the roof, design wider vegetation free zones.
- Add shade tolerant plants in shade environments
- Do not put vegetation underneath runoff discharge
- Design water access to the roof
Growing media is the key component of any green roof system because it is critical to the long and short term success of the plants.

Growing media considerations:

- Enough nutrients, but not enough to promote weed intrusion
- Long term structure (if you incorporate too much organic matter, it will be absorbed by the plants and in a decade the volume of your growing media will dramatically decrease)
- Compaction over time causing lack of aeration
- Long term drainage properties
- Lightweight with a high water retention capacity
The drainage of a green roof is designed to facilitate water runoff from the roof, in order to prevent structural collapse and plant inundation. This layer is also used to retain enough water to ensure plant survival.

**Roof drains** must be surrounded by a vegetation free zone (space filled with stone ballast or pavers) to be accessible for periodic maintenance. All drains and gutters must be protected from clogging caused by accumulation of trash and leaves. Chambers with removable lids are recommended for all drains and gutters.
Design Considerations – Waterproofing Membrane Assembly

A green roof can be installed on any waterproofing material that is a certain thickness and puncture resistant.

These include, but are not limited to polyvinyl chloride (PVC), thermoplastic polyolefin (TPO), ethylene propylene diene monomer (EPDM), metal roofing, modified bituminous sheet roofing membranes and hot fluid-applied rubberized-asphalt waterproofing membranes.

A standing water test should be conducted before the installation of the green roof system (ASTM D 5957)

Asphalt-based and bituminous membranes may be subject to root growth penetration, therefore root barriers are necessary to protect these membranes.
Design Considerations – Slope applications

A 2% roof slope (1/4:12) is the minimum recommended slope for green roofs (International Building Code).

A roof that is too flat can lead to ponding water and damage the plants, unless your green roof system includes a drainage clearance.

Green roofs on structures steeper than 17% (2:12) are more difficult to implement than on flat roofs but they are still possible.

Additional measures should be taken to ensure success of the roof.
Design Considerations – Safety

When installing a green roof, workers should take proper precautions, as they would with any roof installation. This includes taking necessary steps to ensure workers will not fall.

Material stock on the roof should be ballasted to prevent wind uplift problems.
What Guidelines are available for the Planning, Construction and Maintenance of Green Roofs?

There is downloadable German Guideline FLL http://www.fll.de/shop/english-publications/green-roofing-guideline-2008-file-download.html:

The FLL - Green roof guideline is the standard regulatory work for the intensive greening, simple intensive greening and extensive greening of already sealed roofs and building covers.

It also contains details of care and maintenance work to the greened areas and service information for the technical installations.

The FLL - Green roof guideline is also valid for other greening works on roofs and building covers (e.g. special tree plantations, useable grassed areas and other usable areas), planting and lawn works (soft landscaping) and the associated maintenance.
What Handbooks are available for the Planning, Construction and Maintenance of Green Roofs?

There is downloadable Green Roof Handbook


CONTENTS OF THIS HANDBOOK:
• Introduction to Green Roofs
• Green Roof Systems
• Systems With Drainage Plates
• Systems With Granular Drainage
• Systems with Drainage Mats
• Drain Boxes
• Triangular Drainage Channels
• Aluminum Edge
• Slope Stabilization Systems
• Green Roof Components
What Handbooks are available for the Planning, Construction and Maintenance of Green Roofs?

There is downloadable Complete design guide of HYDROPACK® - [http://www.vegetalid.us/green-roof-systems/hydropack-green-roof-system](http://www.vegetalid.us/green-roof-systems/hydropack-green-roof-system):

This document should be used as a design guide only. It is no substitute for the services of an architect and/or engineer, who will enrich the project’s feasibility study with safe working load calculations for the building, wind load data, etc.