Vegetated Roofs (Green Roofs) Combined with Photovoltaic Panels

Solar Garden Roof / Sun-Root™ System

Jörg Breuning, Kimberly Tryba, Ryan Miller rev. 25th September 2013
INTRODUCTION

Green or vegetated roofs reduce the environmental footprint of buildings by re-introducing nature to a place where it existed prior to the structure being built. Living green can substantially reduce a number of urban issues and concerns like heat island consequences, stormwater maintenance, reduction/destruction of natural habitat for beneficial wildlife, and reduction/elimination of native habitat, to name a few. Increasingly, private corporations and government agencies are actively seeking environmentally responsible solutions to address these issues – many times utilizing non-traditional solutions that strike a balance with nature.

Perhaps one of the most effective solutions to be increasingly utilized has been the introduction of green roofs into the urban environment. Long popular in European countries, this technology is essentially in its infancy in the United States, but increased demand for ‘green’ solutions is bringing this concept to fore of the urban conversation. While simple in concept, green roofs offer myriad benefits that significantly address the most complex of urban concerns (e.g. stormwater management, the heat island effect, etc.) and we can expect to see this market continue to grow and blossom.

One of the most recent introductions to this market is one that offers perhaps the most integrated approach to addressing multiple urban, environmental, and alternative energy concerns: the Solar Garden Roof system, which integrates solar panel technology with an extensive green roof solution – offering all of the benefits of both alternative technologies.

Traditionally, solar panel or photovoltaic systems (a.k.a. PV systems) have typically been ground-mounted and installed in rural areas on agricultural land. Rural areas offer ample and inexpensive space for PV and power-producing factories, while allowing the agricultural industry to boost their income. And, since the output of PV systems is significantly related to consistent low ambient temperatures, rural areas have been preferred given the significant cooling effect of the vegetation surrounding the solar panels. However, if clear-cutting of a fully functional forest for installation of super large PV systems is practiced – the environmental value is questionable. As well, large amounts of chemicals, like growth-inhibitors or growth-regulators, applied under rural PV systems may produce a less favorable outcome, because the practice creates dependencies and other environmental issues.

Consequently, there is enough evidence – and it is the strong opinion of Jörg Breuning of Green Roof Service LLC – that the best management practice for the installation of solar solutions is where the power demand is the greatest: Within urban environments. Increasingly around the world, expanses of flat, heat-absorbent or reflective structures, like roof surfaces, parking lots, walls of buildings, and streets have been replaced by natural settings (green roofs, green walls, street trees, green railroad tracks, etc.), to reduce the negative impact of dense and man-made structures. While the comprehensive application of a green (roof) strategy certainly addresses many urban concerns, in some cases, it may create a situation where there is not enough space left for alternative, renewable power within city confines. This paper demonstrates a smart solution that combines technologies and increases the environmental effect and payback.
SOLAR GARDEN ROOF HISTORY

In 2007, Optigreen International AG (Optigreen) introduced the patented Sun-Root™ roof system in Germany as the heart of its Solar Garden Roof system. Since then, the technology has been adopted throughout Europe and has been installed across more than 100,000 sq. ft. across Germany, Austria, Switzerland and Italy.

As such, the Solar Garden Roof with Sun-Root™ system is new to North America, where it is represented via a joint venture between Optigreen and Jörg Breuning’s Green Roof Service LLC / Green Roof Technology (GRS/GRT) – already a 33-year affiliation. In November 2011, Optigreen and GRS/GRT began a strategic outreach within this critical market, where the demand for advanced stormwater solutions and solar technology has increased dramatically – particularly within urban communities (warehouses, universities, schools, public buildings).

SOLAR GARDEN ROOF: FORM AND FUNCTION

The Solar Garden Roof and Sun-Root™ system offers more benefits to the building owner and the environment than any stand-alone solution, since it provides both an alternative energy-generating source as well as a green, insulating layer that significantly decreases demands created by heavy stormwater yields and offers a viable solution to the heat island effect.

The basic principle of the Solar Garden Roof is that it offers a fully integrated solution that marries solar panels with an extensive green roof system. As such, the Sun-Root™ Module is unique not only in its ability to combine two emerging sustainable practices – solar and modern green roof technology – but also in the manner in which each technology compliments the other: The living green roof layer supports the solar panels and maximizes their efficiency, while the planted vegetative material is both protected and irrigated by the solar panels.

THE DESIGN

The Sun-Root™ Module Base has an engineered root design that increases the stability of the system without adding weight. Measuring approximately 32 ft² and made of 100% recycled HDPE, the Sun-Root™ Module is the first green roof system engineered with fully integrated photovoltaic mounts. Each Sun-Root™ Module is ballasted by the green roof growing media and appropriate vegetative material, negating the need to penetrate the roof membrane (the water-proofing) to mount the solar array.

And the Sun-Root™ Module design is incredibly stable: In 2009/2010 it successfully passed German wind canal testing with maximum wind speeds of 160 km/h or 100 mph. Extensive monolithic green roofs (or in-place systems) by Optigreen have proven in the last four decades to be reliable for much higher wind speeds.

The versatile Sun-Root™ Module or Solar Garden Roof supports all current major brands of PV panels and future systems in according sizes. Solar thermal solutions (e.g. vacuum tubes) up to a length of 4ft can be an alternative.

The system’s solid construction and easy accessibility also allows an easy upgrade or replacement of PV elements or inverters that become less productive or are defective. The surrounding green roof protects the sensitive water proofing at all times and against almost any imaginable impact.
Bird’s eye view of Sun-Root™ Module Base
**BENEFITS: Symbiotic Relationship Between Solar and Vegetation**

In order to achieve full system integration, the innovatively designed modules of the The Sun-Root™ System are fully integrated into the drainage layer of the extensive green roof system. The Sun-Root™ Modules provide enhanced water retention and an optimal 30° angle for PV panels situated in North America and Canada. For locations in Africa, parts of Asia, Central/South America, Alaska, Scandinavia, and Siberia, the system comes with an adjustable mounting system that allows angles between 22°-38°.

A complete Sun-Root™ System will see an increase in production efficiency due to the system’s design that maximizes passive cooling by a healthy layer of vegetation through enhanced water retention, evapotranspiration and thermal collection. It is the most effective way to improve PV efficiency and reduce the rate of thermal degradation of solar cells.

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**Solar Garden Roof: with Sun-Root™ - Setup and Function.**
BENEFITS: Energy Production and Efficiency

One study, conducted by the Department of Mechanical Engineering at The University of Hong Kong initiated by Köhler, et al. (2002), was set up as a green roof with a PV racking system attached to plastic boards underneath. The study concluded that “the PV system [using an] integrated approach generates 8.3% more electricity than the stand-alone option”1. The University of Hong Kong attempted to combine an extensive green roof with photovoltaic panels for research purposes. The integration of both systems was done without consideration to improve the benefits of an extensive green roof and photovoltaic system. However, the results of their study clearly demonstrate a higher power production on a roof that is naturally cooled by vegetation:

Increasingly, PV manufacturers offer cooling solution duct systems (including water-cooled PV elements) that utilize the heat built-up behind the solar panels to increase their efficiency. It is well researched and well known in the solar industry that the heat build-up behind PV modules reduces the electrical output by 0.4-0.5% for every 1°C above its rated output temperature, which is 25°C (77°F). A typical rooftop PV array may measure 55 to 75°C (131 to 167°F), which means its electrical output would fall by 12% -25% below the nameplate rating. The studies mentioned in this document and other green roof temperature studies indicate substantially lower temperature on green roofs. Combined with the 30° angle and sufficient air movement under the panels the vegetation on large Solar Garden Roofs (20kW or more) consequently have the potential to increase the output by 10-20% depending on the climate location and comparing to a traditional solar installation on a black or reflective roof.

Lately, reflective roof surfaces are controversial because the reflective light can also heat the PV from behind or affect the longevity of inverters mounted under the Solar Panel.

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* Dr. Sam C. M. Hui and Miss S. C. Chan  Department of Mechanical Engineering, The University of Hong Kong Pokfulam Road, Hong Kong
BENEFITS: Environmental Impacts

Environmentally Friendly Materials

All components of the Solar Garden roof system have proven their longevity (25 years and more). Longevity of material reduces costs of replacement associated with waste going to landfills. The components – if ever replaced – can be recycled for the exact same purpose, with very little impact (energy). Furthermore, most components are manufactured either out of recycled materials (HDPE) or materials that are typically locally available (less than a 500 mile radius). Most aggregates in the growing media are mineral and allow endless recycling for the same purpose over the next 5,000 – 10,000 years (some of which are already 50,000 years old!). The vegetation undergoes a consistent natural renewing process or, if not wanted anymore, is easy to compost and add to new green roof growing media.

Heat Island Effect

Like nature, modern green roof technology – also known as low-maintenance, extensive green roofs – can greatly affect the roof temperature profile by cooling surface layers and, as such, has become the preferred solution to reduce the heat island effect in cities. Multiple global studies over the last 40 years testify that living vegetation substantially reduces the ambient temperature by adsorbing light and transferring heat into evaporative cooling. These studies also demonstrate that vegetation greatly reduces the ambient temperature especially on sunny days.* The shade on surfaces created by plants contributes in additional effective cooling independent of the size (height) of the plant. The moderate Albedo value of vegetation also reduces the reflection of sun light on other surfaces (particles in the air, structures, etc.) and prevents light-to-heat transformation. (Additional reading: “Green Roofs Are Not Created Equal: The Hydrologic and Thermal Performance of Six Different Extensive Green Roofs and Reflective and Non-Reflective Roofs in a Sub-Tropical Climate.” Mark T. Simmons & Brian Gardiner & Steve Windhager & Jeannine Tinsley, Published online: 25 July 2008, et al.)

Stormwater Management

Modern green roof technology – and extensive green roofs in particular – is the best and most efficient solution to reduce stormwater-impervious structures. The reduction of stormwater run-off, the delay of run-off, and improvement of the run-off water has been studied significantly over the last three decades. All industrialized and emerging countries are currently considering a rapid increase the implementation of modern green roof technology to ease their dramatic stormwater loads and to improve water quality. Depending on the materials of the green roof layers, the performance and long-term reliability can vary. Most un-irrigated green roof solutions with healthy and diverse vegetation retain between 50-75% of the annual rainfall – assuming the entire depth of the system is greater than four inches. The reduction of stormwater run-off can save billions of tax payer dollars, in locations where existing sewer systems are not engineered for higher stormwater loads.

ADDITIONAL BENEFITS:

Fire-proofing

In the past, roof-mounted PV Systems were less efficient because of the higher ambient temperature of a roof. There have been times when PV Systems automatically shut-off when the roof temperatures rose over a certain temperature. Inverters (electric components) are even more heat-sensitive and there have been a few, very rare cases where they’ve destroyed or rarely ignited especially when the solar arrays were installed on reflective roofs. Integration of a fire-resistant vegetative layer (e.g. sedums) and low-combustible growing media around the solar array virtually eliminates this possibility.

Installation & Maintenance

A Solar Garden Roof eliminates the need for installation of a racking system for the PV panels since this is already integrated in the Sun-RooftM Module. The 30° angle of the PV reduces the build-up of dust and algae in the panels, reducing cleaning cycles by 50-80%. The vegetation layer protects the roofs against environmental and mechanical impacts and, once established, requires no irrigation and very little maintenance- as is not the case with other extensive green roof systems.
BENEFITS: ROI (Return on Investment)

It is also important to highlight the costs and paybacks associated with the investment in the Sun-Root™ Solar Garden Roof. The costs of the solar + green roof are competitive with most installations of one or the other. The money that would have been spent on mounting and racking the solar array is now used to create a living roof (green roof) that ballasts the system, retains stormwater, and doubles or triples the lifetime of the roof membrane (waterproofing). The Sun-Root™ Module is engineered with two functions: Advanced retention/drainage board and a mounting system for solar. This reduces the amount of different materials required and installation time associated – resulting in cost savings. Avoiding unnecessary materials is the best practice to reduce costs and to protect the environment (although fewer materials might not contribute to more LEED™ points).

To support the growth of renewable energy solutions, the federal government has put in place the Business Energy Investment Tax Credit, which allows the building owner to write-off 30% of the costs associated with the installation of solar panels during the first year. Many states, utility companies, and local governments also have additional incentives in place, to make the decision to go solar financially attractive to the owner.

Each year, the solar green roof system will produce Solar Renewable Energy Credits (SRECs) that will equal approximately 1kW of energy. SRECs can be sold to brokers, aggregators, and/or to local utility companies who are required to purchase these credits as part of their renewable energy portfolio.

![Chart: Green Roof Service LLC / Green Roof Technology / SolarGain (only solar incentives and green roof as an ballast)](chart.png)

Many of our calculations for prospective clients show a payback within the first five (5) years – some even within as few as three (3) years – depending upon the size of the system installed and grants/incentives available. The chart above illustrates how the paybacks are factored when analyzing the total costs over the Sun Root™ system’s 25-year warranty.

With a 20-25 year warranty assuring the efficiency of the photovoltaic array, the owner can expect significant paybacks throughout and beyond the 25 years. Once the return on investment is realized, the owner will continue to enjoy the energy savings and revenue created from the rooftop.
Most cities also provide incentives for the installation of green roofs (on average, $2-$10/sq ft) and allow the combination of both since the green roof is fully integrated, seamless and at the same time ballast for the PV system.

In some cases, the costs of fully integrated and combined systems can be reduced or even eliminated through a Power Purchase Agreement (PPA). Especially for non-profit organizations, these type of investments have a very high value since their energy costs can be locked in over 10-20 years – and the system can provide highly educational purposes for students (including curriculums and on-time visual monitoring systems). The system may also be easily combined with other vegetation forms, like edible roof gardens, amenity space, or research units.

A green roof shields the waterproofing membrane against environmental and mechanical impacts. A standalone green roof typically saves the owner at least one re-roofing after approximately 15-20 years. This value to the owner is also realized with a Solar Garden Roof.

Heating and cooling benefits of green roofs (and reflective roofs) are often discussed as being marginal; although there are definite added values, the benefits can be inconsistent since they are weather or climate-dependent. Given that a green roof extends the lifespan of a roof’s waterproof membrane so dramatically, the insulation below the green roof requires considerations of energy needs/costs for 25 years from the date of installation. With this consideration, an ideal insulation below a green roof or Solar Garden Roof would be r-45 or higher. This additional insulation will provide remarkable benefits from day one.

Currently stormwater fees are implemented in most North American cities and European countries – and even those fees that have been in place for decades can be reduced or eliminated with the installation of green roofs and Solar Garden Roofs. Note: These savings strongly depend on local regulation and on project size; a typical ROI calculation does not consider that but certainly is an added monetary value.

STATE-BY-STATE INCENTIVES FOR RENEWABLE ENERGY & EFFICIENCY

DSIRE™ is the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States. Established in 1995, DSIRE™ is currently operated by the N.C. Solar Center at N.C. State University, with support from the Interstate Renewable Energy Council, Inc. DSIRE™ is funded by the U.S. Department of Energy. (http://www.dsireusa.org/)
SOLAR GARDEN ROOF IN ACTION

The first Solar Garden Roof with the advanced combination of solar panels and extensive green roof in North America was installed in Spring 2012 atop the New York City Parks & Recreation (NYCPR) Administrative Office Building on Randall’s Island (and eye-level with commuters on the RFK/Triboro Bridge). Since 2006, this 30,000 square foot center has served as a green roof test facility and currently showcases almost three-dozen systems – with the Sun Root™ as the only green roof system in the facility that fully integrates solar panel arrays.

Artie Rollins, Chief of Technical Services at NYCPR, was drawn to this new technology as a means of harnessing solar power to supplement the building’s main electrical system – without the need of penetrating the roofing membrane. Since he approved its installation, Artie has become a solid strong supporter of the system.

“When the visitors of the green roof test facility – more than 100 tours a year – reach the Solar Garden Roof, the reaction is consistently one of amazement,” Artie said in an interview in January 2013. “People are impressed about the system’s advantages and its performance.”

Power Generation

The four solar panels generate and store enough energy during the day to sufficiently power a series of rooftop LED lights throughout the night. The 1kW system is not connected to the building’s electrical system or the power grid. Instead, the power is stored in powerful solar batteries. The application doesn’t require any additional penetration of power lines through the roof deck and waterproofing membrane, and these types of systems are also ideal for locations where no power is available (e.g., vacation homes, remote cabins, etc.).

Wind Tolerance

Although controlled wind studies have already proven the strength of this system, we are now able to report the first field wind tests. Hurricane Sandy\(^2\) (a.k.a. “Superstorm Sandy”) made landfall in late October 2012, only six (6) months after installation, and left without moving the Sun-Root\(^\text{TM}\) Solar Garden Roof an inch. New York City reported maximum sustained winds at 85 mph with some gusts reaching 92 mph\(^2\). Upon visiting the site a week after the storm, we found that the original placements of the Sun-Root\(^\text{TM}\) withstood the winds without a shift and remained fully functional. As expected, the vegetation (coverage was 50% at this time) was also fully intact, with no noticeable impact or wind erosion.

Maintenance

Just a year after the installation and area was planted with sedum plugs (1 per sf\(^2\)), the entire demonstration area is fully grown in. With four maintenance visits in the first year to remove unwanted plants, and one treatment with a 5-5-5 fertilizer that included micro nutrients, the system is considered as being extremely low maintenance. The plants were only once manually irrigated – just after planting. Two maintenance visits were performed in the second year (approx. 30 min each) to spot-check the vegetation coverage and inspect the equipment.

The Solar Garden Roof at Randall’s Island – after the first year – withstanding Superstorm Sandy

Solar Garden Roof with Sun-Root™ at Randall’s Island – fully vegetated under the Solar panel – never irrigated.
OUTLOOK (For CFOs)

The growth of the renewable energy market is fueled by rising energy costs. In fact, according to the International Energy Agency (EIA), “Energy demand has risen at just over 2 percent per year for the past 25 years and will continue to climb at about this same rate over the next 15 years if current energy use patterns persist.”

As energy costs continue to rise, now is the best time to invest in renewable energy. With each passing year, consumers will pay more for the same amount of energy they used the previous year. The Sun Root™ system is one of the most efficient and cost-effective solutions by which private and corporate consumers can invest in a technology that not only generates energy and revenue – but also allows them reduce their dependence upon traditional utility companies and energy sources.

Mark Winkler, CFO, J.W. Winco: “There’s no ROI on a conventional roof, roof replacement is a requirement no matter what, and even a normal re-roof is a costly endeavor.”

The rising energy costs are only one aspect. Other aspects (not considered in the 25 year cost analysis) are reduction in annual stormwater fees, extending the lifespan of water proofing (2x -3x), increase of environmental awareness and obtaining/retaining a positive (green) image in the community and innovative advertising carrier.

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3 U.S. Energy Information Administration 1000 Independence Ave., SW Washington, DC 20585
Example - Solar Garden Roof (for CFOs)

From Drawing Board to Reality
# 25-YEAR COST ANALYSIS  
(\textit{w/o Green Roof Incentives})

## Baltimore, MD

### 240W Modules (Flat roof)

25 Year Projection - MARYLAND

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### IRR Calc.

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CONCLUSION

The integrated Solar Garden Roof system can significantly address complex urban environmental issues like energy conservation, stormwater management, and the heat island effect – with myriad benefits not offered by traditional solutions for urban environments:

- System offsets rising traditional energy costs through generation of alternative power
- Incentives and grants minimize initial investment
- SREC’s and electricity savings create annual income
- Substantial and active cooling for Solar panels
- Increase in lifetime of Solar panels and inverters
- Reduction and/or elimination of stormwater fees
- Significant reduction in heat island effect
- Reduction in environmental impact
- Insulating vegetation layer extends the life of roof membrane / water proofing
- Efficient, earth-friendly, and durable design ensures easy upgrades, accessibility and flexibility
- Accurate calculable payback

Though there is an additional upfront expense for building an integrated system – vs. installing a bare roof or open roof – these costs can be substantially diminished when combining green roof systems with advanced solar systems and applying the many financial incentives available over the course of the green roof’s lifespan.

By embracing the future of this technology and its substantive benefits, consumers and corporations alike in both the private and public sectors will not only reap the financial rewards of living ‘green’ – but also reduce on a global scale the negative impact that dense and man-made structures have had on the environment.