**Key findings**:

- Compared to a black roof, a 3-inch to 6-inch green roof covering 10,000 feet has a Net Present Value of $2.70 per square foot per year, Payback of 6.2 years and an Internal Rate of Return of 5.2% nationally.
- The longevity of green roofs has the greatest effect on savings, whereas installation and maintenance have the greatest effect on cost (maintenance costs are even greater than the installation premium).
- Over a 50-year period, stormwater, energy, equivalent carbon dioxide ($CO_2e$, which measures the potential global warming effect of a greenhouse gas) and community earnings of green roofs more than made up for the increased premium of installing, maintaining and replacing them. Results can vary depending on one's relationship to the subject real estate.
- The fewer floors a building has, the greater the energy savings are for a green roof compared to a black roof.
- The greater the surface area, the greater the stormwater management savings are for a green roof compared to a black roof.
- Cost savings will increase as stormwater regulations become more stringent and green roofs become more acceptable as mitigation measures.

A major goal of this report is to compare the costs of green roofs with the benefits they provide. This requires an understanding of the costs of green roofs, a quantification of the benefits, savings and value produced by green roofs, a comparison of these costs and benefits, and an analysis of the results. This section includes each of these required steps.

## 3.1 PURPOSE

This report has thus far described many of the costs and benefits of installing a green roof instead of a conventional black roof. However, to put the cost and benefit of each type of roof in context, an analysis was conducted in which the expected cash flows of both green and conventional roofs were modeled over time. For instance, the additional cost of installing a green roof was accounted for in year one but was followed by years of energy savings as a result of this installation. This analysis thus gives a financial overview of a green roof as an investment, and allows this investment to be compared to similar, building-level investments. Building owners, as do most investors, typically choose to make investments with the greatest expected return, though they often weigh competing, non-financial influences such as building image, as well.

## 3.2 METHODOLOGY

The cost-benefit analysis presented in this section is based on a direct comparison between installing either a black roof or a state-of-the-art extensive green roof as a replacement for an existing conventional roof. The costs and benefits of the extensive green roof are averaged between a 3-inch multi-course extensive profile and a 6-inch semi-intensive profile. Because the size of green roofs on commercial and institutional projects can vary greatly, this study included three roof sizes: 5,000, 10,000, and 50,000 square feet.

The relative costs, cost-saving benefits and added value of a green roof versus a black roof over a 50-year timeframe was then accounted for and discounted back to present value. Six separate cash flows were created to allow data segregation and identification of the relative benefits:

- Installation, replacement and maintenance
- Stormwater
- Energy
- Carbon
- Community benefits
- Real estate effects

The cash flows from the following benefits were not included in the analysis:

- Urban agriculture
- Acoustics
- Job generation
- Productivity

The costs and benefits are experienced by the following:

- Directly by the developer through installation, rent or operations,
- By the municipality through reduced infrastructure maintenance or replacement costs,
- By the community through improved aesthetics, biodiversity or job generation, or
- To building occupants through productivity gains or improved health (productivity and improved health was not integrated into this analysis due to the difficulty in assigning a particular performance attributable to either roofing type).

For transparency purposes, rather than aggregating all of the data and stating an overall **net present value (NPV) or internal rate of return (IRR)**, this analysis openly shares its data and keeps the results separated to demonstrate the relative costs and benefits of green roofs versus their conventional counterparts.

## 3.3 ASSUMPTIONS

Users should be aware that the intent of this analysis is to present "average" costs and benefits on a very broad, national level and on a more specific, metropolitan level, for Washington DC. Results may differ for specific states or municipalities.

### 3.3.1 COST

The decision of whether to install a green roof should be considered on a case-by-case basis. Variability in structure, municipality, ownership, tenant, investment, technology, climate and other aspects requires specific attention to ensure accuracy. This analysis aims to limit some of these variables by focusing only on roof replacements and on the financial performance "premium" between state-of-the-art extensive green roofs and state-of-the-art black roofing. The cost-benefit model includes inflation, growth rates for labor and materials, energy, stormwater, community benefits, diminishing returns (based on expected increase in supply), a discount rate evaluation, a 50-year timeline and community (public) benefits of green roofs. A detailed description of the assumptions is in Appendix B.

For the purposes of this study, we conducted a cost-benefit analysis comparing the two simplest, beneficial and least expensive examples of the extensive and intensive varieties of green roof with a conventional, black roof. These were a 3-inch multi-course extensive roof with a geosynthetic drain layer, and a 6-inch semi-intensive roof.

The 3-inch profile is the minimum recommended for maintenance requirements and stable plant coverage without permanent irrigation, and is used in places where stormwater management is the main reason to install a green roof. The 6-inch profile includes four inches of growth medium over two inches of drainage medium, and includes permanent base-level capillary irrigation to sustain plants. These roofs are typically used where garden aesthetics and biodiversity are priorities, in addition to stormwater management. Performance characteristics, layers, recommended plant lists and wet weight loads (see *Section* 4.1.1 for structural issues) of both roofs examined are detailed in Appendix A.

**Key findings**:

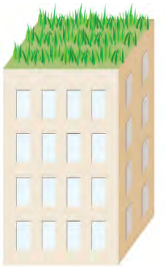
- Green roof installation costs per square foot decrease as size increases.
- The installed cost premium for multi-course extensive green roofs ranges from $10.30 to $12.50 per square foot more compared to a conventional, black roof.
- The installed cost premium for semi-intensive green roofs ranges from $16.20 to $19.70 per square foot more compared to a conventional, black roof.
- Annual maintenance for a green roof is typically higher than for a black roof, by $0.21 to $0.31 per square foot.

***Green roof installation costs***

This analysis developed a standardized cost for both intensive and extensive roofs using the federal prevailing wage rates for Washington DC, and current material costs.* As demonstrated in Figure 21, extensive green roofs are approximately $6 to $8 per square foot cheaper to install than semi-intensive green roofs, and in both cases larger green roofs cost less per square foot to install than smaller green roofs.

This analysis found that the typical installation cost for a green roof depends on its size, with the price per square foot decreasing as the size increases. The cost premium of installing an extensive green roof ranges from $10.30 to $12.50 per square foot more compared

**5,000 sqft**



**10,000 sqft**

**50,000 sqft**

*Roofmeadow verified these costs by comparison with projects that it has completed in each green roof profile/size configuration. The specific projects are not discussed for reasons of client confidentiality.

to a black roof, while installing a semi-intensive green roof costs from $16.20 to $19.70 per square foot more compared to a black roof (see *Section* 4.2 for installation issues).

***Green roof maintenance***

The first years of a green roof's existence are considered an **establishment period**, in which maintenance is critical to the roof's long-term success and maintenance requirements are greatest. Maintenance of a green roof includes weeding, harvesting cuttings and distributing them in bare spots to improve coverage, checking for loss of growth medium, and inspecting for other potential problems. Maintenance costs will be higher any time a green roof includes a landscaped design, as workers will also need to spend time maintaining the design aesthetic. A typical maintenance crew includes two workers, though more may be needed for a larger roof. For this study, labor hours were rounded up to the next half-day for cost estimating purposes.

A minimum of three maintenance visits per year is recommended for an extensive green roof during the establishment period. The typical labor requirement is 4 person-hours per 1,000 square feet per year, or 1.33 person-hours per 1,000 square feet per visit. Maintenance requirements will decrease after the establishment period; this analysis assumes a reduction to two visits a year for this type of green roof.

For an intensive green roof established with plants listed in Appendix A, a minimum of four maintenance visits per year is recommended during the establishment period. The spring and fall visits will be more labor intensive, requiring cutting and removal of dead grasses, removal of organic litter, and other tasks. The typical labor requirement is six person-hours per 1,000 square feet per year, or 1.5 person hours per square feet per visit. After the establishment period, maintenance demands will decrease but the number of visits will hold steady at four per year (see *Section* 4.3 for maintenance issues).

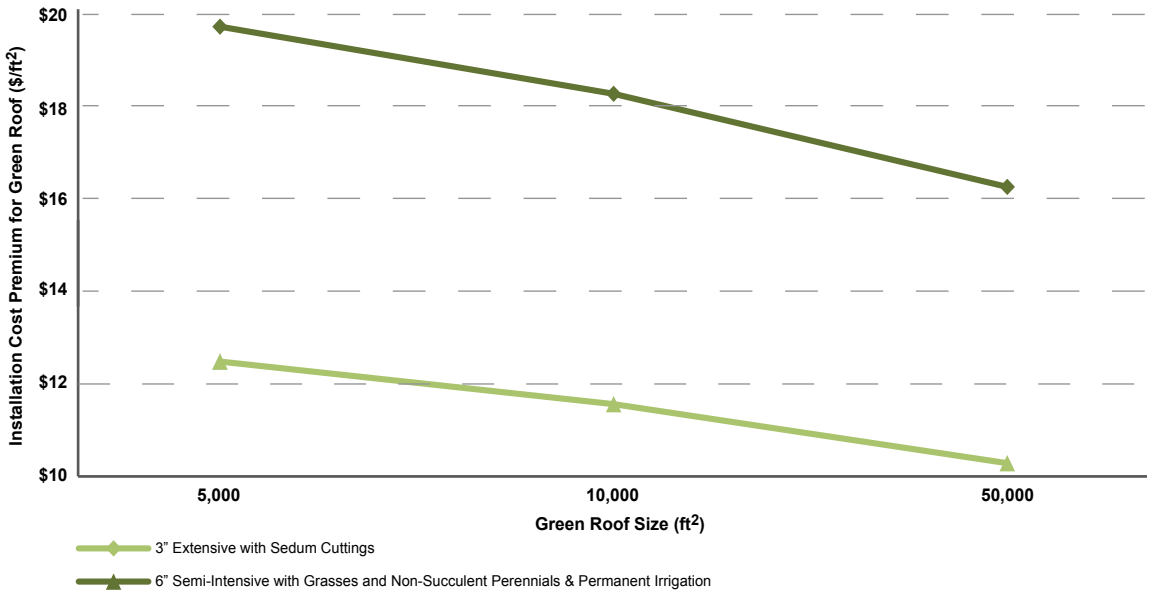



Figure 21: Green roof installation premiums

In general, maintenance costs for both types of green roofs are greatest during the establishment period, or the two years after installation. Intensive roofs require more frequent and longer maintenance visits than extensive roofs, both during the establishment period and afterward.

Annual maintenance of green roofs costs from 21 cents to 31 cents more per square foot per year than maintenance of a black roof. White roofs typically need more maintenance than black roofs, as they must be kept free from debris to continue to reflect solar radiation as expected.

### 3.3.2 BENEFITS

The benefits of an extensive green roof versus a conventional black roof are described at the end of each subsection in the Benefits Section. The benefits specifically accounted for in this analysis fall in two groups:

- Those that **directly affect owners/occupants/ investors**, including installation, replacement and repair, stormwater and energy
- **Other financial impacts**, including greenhouse gas savings, market-based savings, and community benefits.

Additional details can be found in Appendix B of this report.

## 3.4 RESULTS

The results presented below are itemized to show the relative differences in costs and benefits, in an effort to help the reader to understand the relative impacts on the costs and benefits of installing a green roof.

### 3.4.1 NET PRESENT VALUE PER SQUARE FOOT OF ROOF

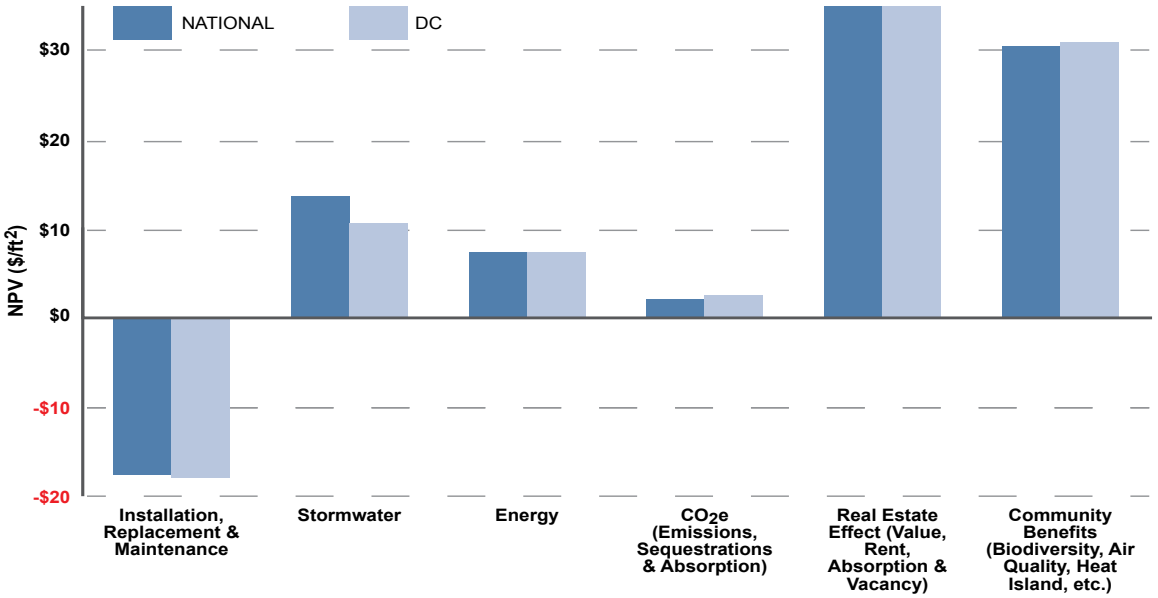



Figure 22: NPV cost-benefit analysis results of green roof versus black roofs

**Key terms**:

- **Net Present Value (NPV)** is a measure of the potential profitability of an investment. It takes the expected value of the future costs and benefits associated with this investment, and accounts for the effect of inflation. A positive net present value means an investment will produce greater returns over the time frame being considered than an alternate investment.
- **Internal Rate of Return (IRR)** is a measure of the expected annual financial benefit yielded by an investment over a given time frame (e.g., an IRR of 6% suggests a stream of cash growing, on average, at 6% per year). This benefit can be compared with the expected yields of other investments over the same period.
- **Payback** is the number of years it takes to recoup an initial investment through the income from that investment.
- **Return on Investment (ROI)** is percent of money gained or lost on an investment, relative to the initial cost.

**Over a 50-year period:**

- The installation, replacement and maintenance of a green roof has the greatest negative impact on net present value at a cost of approximately $18 per square foot of roof.
- Stormwater and energy savings make up for this cost by providing a benefit of approximately $19 per square foot of roof.
- Benefits to the community have the greatest positive impact on net present value at a savings of almost $38 per square foot of roof.

Table 8: Cost-benefit analysis results of green roof vs black roofs

| NATIONAL LEVEL RESULTS | ROOF SIZE ($ft^2$) 5,000 | 10,000 | 50,000 |
|---|---|---|---|
| **Impact on Owners/Occupants/Investors** | | | |
| **Initial Premium,** $/ft² of roof (extra cost of installing a green roof instead of a black roof) | -$12.6 | -$11.4 | -$9.7 |
| **NPV of Installation, Replacement, & Maintenance**, $/ft² of roof | -$18.2 | -$17.7 | -$17.0 |
| **NPV of Stormwater,** $/ft² of roof (savings from reduced infrastructure improvements and/or stormwater fees) | $14.1 | $13.6 | $13.2 |
| **NPV of Energy**, $/ft² of roof (energy savings from cooling and heating) | $6.6 | $6.8 | $8.2 |
| **Net Present Value** (installation, replacement & maintenance + stormwater + energy NPV) | $2.5 | $2.7 | $4.5 |
| ***Internal Rate of Return (IRR)*** | *5.0%* | *5.2%* | *5.9%* |
| ***Payback**, years* | *6.4* | *6.2* | *5.6* |
| ***Return on Investment (ROI)*** | *220%* | *224%* | *247%* |
| **Other Financial Impacts (less realizable)** | | | |
| **NPV of $CO_2e$,** $/ft² of roof (emissions, sequestration & absorption) | $2.1 | $2.1 | $2.1 |
| **NPV of Real Estate Effect,** $/ft² of roof (value, rent, absorption & vacancy) | $120.1 | $111.3 | $99.1 |
| **NPV of Community Benefits**, $/ft² of roof (biodiversity, air quality, heat island, etc.) | $30.4 | $30.4 | $30.4 |

| WASHINGTON DC RESULTS | ROOF SIZE ($ft^2$) 5,000 | 10,000 | 50,000 |
|---|---|---|---|
| **Impact on Owners/Occupants/Investors** | | | |
| **Initial Premium,** $/ft² of roof (extra cost of installing a green roof instead of a black roof) | -$10.7 | -$9.5 | -$8.0 |
| **NPV of Installation, Replacement, & Maintenance**, $/ft² of roof | -$18.1 | -$17.9 | -$17.7 |
| **NPV of Stormwater,** $/ft² of roof (savings from reduced infrastructure improvements and/or stormwater fees) | $11.0 | $10.5 | $10.2 |
| **NPV of Energy**, $/ft² of roof (energy savings from cooling and heating) | $6.8 | $6.8 | $8.3 |
| **Net Present Value** (installation, replacement & maintenance + stormwater + energy NPV) | -$0.2 | -$0.6 | $0.7 |
| ***Internal Rate of Return (IRR)*** | *4.3%* | *4.2%* | *4.7%* |
| ***Payback**, years* | *6.6* | *6.5* | *6.0* |
| ***Return on Investment (ROI)*** | *198%* | *194%* | *209%* |
| **Other Financial Impacts (less realizable)** | | | |
| **NPV of $CO_2e$,** $/ft² of roof (emissions, sequestration & absorption) | $2.6 | $2.6 | $2.6 |
| **NPV of Real Estate Effect,** $/ft² of roof (value, rent, absorption & vacancy) | $98.4 | $88.2 | $74.1 |
| **NPV of Community Benefits**, $/ft² of roof (biodiversity, air quality, heat island, etc.) | $30.9 | $30.9 | $30.9 |

In regards to the ROI, on a national level, a dollar invested in a green roof today suggests a return of $1.29 in today's dollars after 50 years. For Washington DC, the same dollar invested would yield one dollar in return (in today's dollars); in other words, the green roof investment is the same as an average, alternative investment of 4.4%. If $CO_2e$ and community benefits were added in, that same dollar invested would result in $3.19 and $3.57, respectively.

### 3.4.2 SENSITIVITY ANALYSIS

A sensitivity analysis was also conducted to identify the more important variables based on their ability to impact the total NPV. The factors that most influence the value/costs of a green roof are:

| HARD COST VARIABLES | CHANGE IN TOTAL NPV PER 1% CHANGE IN VARIABLE |
|---|---|
| Roof Longevity (1-year change) | 13.24% |
| Installation Costs | 11.32% |
| Discount Rate | 4.89% |
| Maintenance Costs | 3.38% |
| Energy Savings | 2.51% |
| Stormwater Equipment Cost | 1.44% |
| Stormwater Surcharge | 1.35% |
| Green Roof Risk Contingency | 1.21% |

### 3.4.3 NPV BY REAL ESTATE RELATIONSHIP

The NPV analysis in *Section* 3.4 provides seven different areas of either costs or benefits, however, these costs and savings vary because of significant differences in ownership. Additional analysis appropriately separates costs and benefits according to the relationship of each to the subject real estate:

- Owner
- Owner/occupant (i.e., an owner who occupies its building)
- Tenant
- Community

The results in Table 9 and Figure 23 indicate NPV per square foot of roof based on ones relationship to real estate. The assumptions of the analysis are in Appendix B.

Table 9: NPV of a green roof based on ones relationship to its real estate

| | OWNER | OWNER/ OCCUPANT | TENANT | COMMUNITY | MARKET EXPECTATION (YEAR 1) |
|---|---|---|---|---|---|
| **NATIONAL** | $0.06 | $6.0 | $5.4 | $29.8 | $12.9 |
| **WASHINGTON DC** | -$1.0 | $3.1 | $4.1 | $30.3 | $10.0 |
| **TOP 2 DRIVERS** | Maintenance Costs & Avoided Stormwater Infrastructure | Maintenance Costs & Avoided Stormwater Infrastructure | Maintenance Costs & Energy Savings | Biodiversity & Urban Heat Island | Longer leases & Rent |

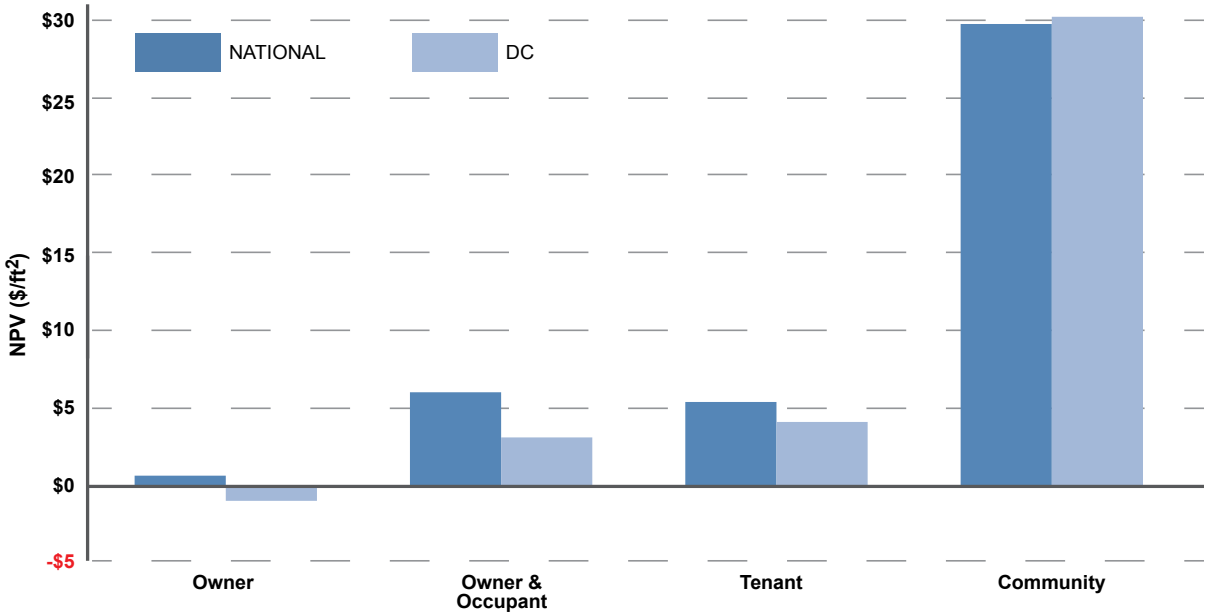



Figure 23: NPV of a green roof based on ones relationship to its real estate

## 3.5 DISCUSSION

The added cost of installing a green roof is mostly made up for by its increased longevity; however, the added maintenance costs are significant. Over a 50-year period, the stormwater, energy, carbon dioxide equivalent ($CO_2e$, which measures the potential global warming effect of a greenhouse gas) and community earnings of green roofs more than made up for the increased premium of installing and maintaining them. A detailed look at the net present value per square foot of roof on a cash flow basis shows an installation and replacement cost of -$1.10, as compared with a maintenance burden of -$16.89, for Washington DC.

Although building and site characteristics, stormwater regulations and energy costs vary greatly, long-term savings of green roofs help make up for their maintenance costs. The fewer floors a building has, the greater the energy savings will be. The greater the surface area of a green roof as a proportion of the overall site surface area, the greater the stormwater management savings will be. These savings are expected to increase as stormwater regulations become more stringent and green roofs are increasingly viewed as an acceptable stormwater mitigation measure.

As energy prices increase, the energy-related savings also will increase. The additional analysis suggests that the costs and benefits vary significantly depending on perspective. An owner/operator such as the GSA might yield strong financial benefits from replacing non-green roofs of their assets with green roofs. In the National Capital Region, if green roofs were to replace conventional roofs on all 54 million square feet of real estate (an estimated 5.9 million square feet of roof area*), this cost-benefit analysis projects a 50-year NPV of $22.7 million,† or $0.42 per square foot of building area. The community benefits in the National Capital Region could total almost $180 million, or $3.30 per square foot of building area.

Significant consideration should be given to competing and symbiotic initiatives. This cost-benefit analysis does not consider the question of whether an existing building even needs a new roof. The decision of whether to install a green roof should consider the impact of this work on building tenants.

This analysis supports the general cost-benefit analysis finding that green roofs offer great potential savings and benefits. The specific real estate effect of green roofs, or their impact on real estate economics from a market and financial perspective, yields varying benefits that can affect a building's net operating income and market valuation. A onetime valuation of this real estate effect is similar to the NPV of the actual benefits, whereas the NPV of these ongoing savings and a greater building value are hard to realize.

The various aspects considered in the community portion of the cost-benefit analysis are only part of the actual impact of a green roof. If real estate value and the productivity of neighboring properties were included, the benefits would potentially far outweigh the costs. Similarly, the value and productivity of the building itself could add to the already positive NPV. Market acceptance of green roofs and the value of the work occurring in the space are two areas that need to be better understood before they can be accounted for.

*This assumes a 9-story average for all GSA buildings in the National Capital Region

† This assumes a 24% owner/occupancy and 76% tenancy for GSA in the National Capital Region

**GSA Region 3 - FEMA Disaster Operations Center, Winchester, Virginia**

A 50,000 square foot extensive green roof planted on the new LEED Certified building (2008).