DDC
COOL & GREEN ROOFING MANUAL

NEW YORK CITY DEPARTMENT OF
DESIGN + CONSTRUCTION

Prepared for
NYC Department of Design & Construction
Office of Sustainable Design by

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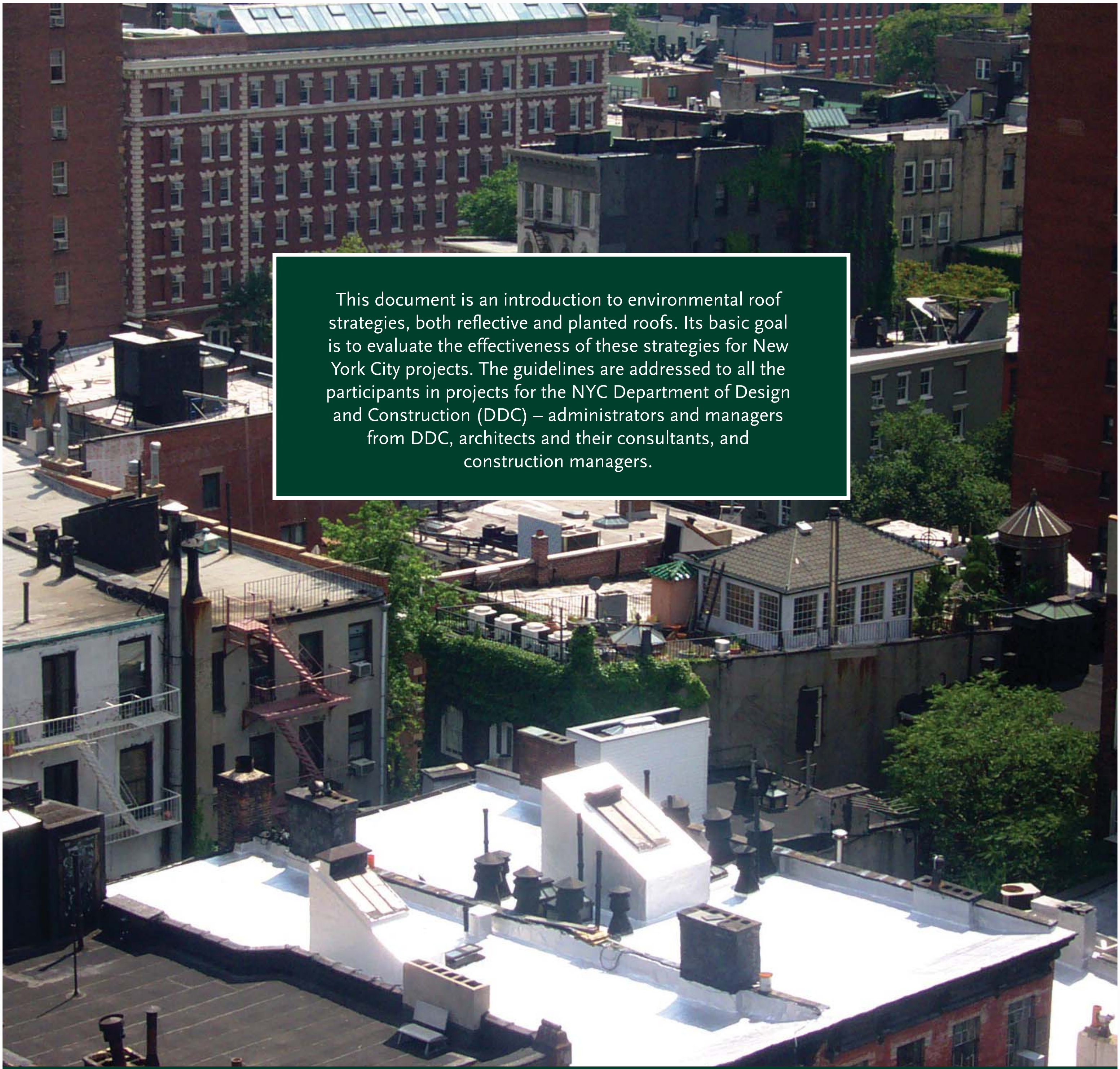

This document is an introduction to environmental roof strategies, both reflective and planted roofs. Its basic goal is to evaluate the effectiveness of these strategies for New York City projects. The guidelines are addressed to all the participants in projects for the NYC Department of Design and Construction (DDC) – administrators and managers from DDC, architects and their consultants, and construction managers.

EXECUTIVE ACKNOWLEDGEMENTS
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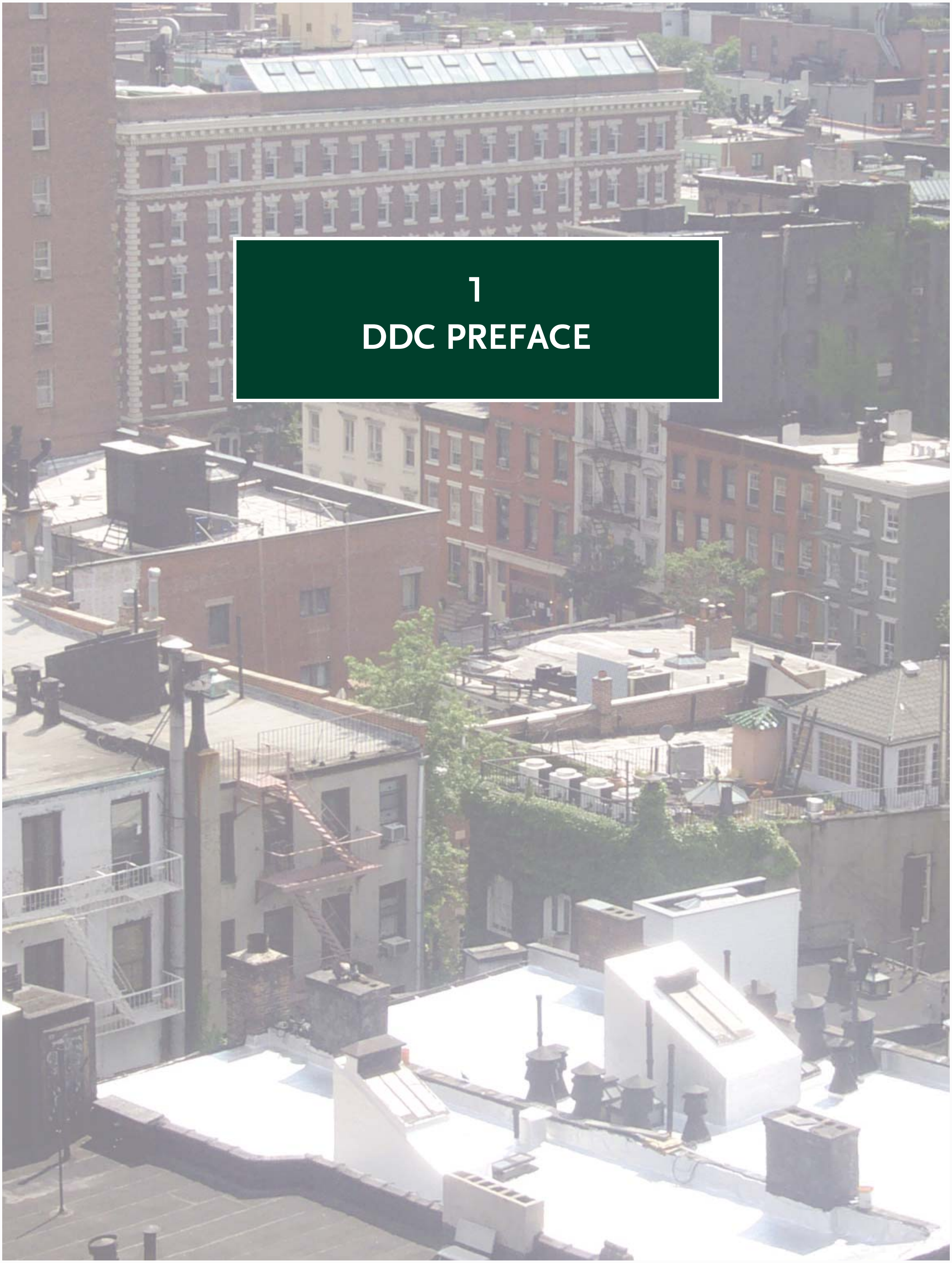

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DDC PREFACE

PREFACE NYC DEPARTMENT OF DESIGN AND CONSTRUCTION

In recent years, there has been great interest in the potential of two roofing strategies – "cool" (or light colored) roofs and "green" (or planted) roofs – to reduce the energy consumed by individual buildings, as well as mitigate large-scale urban environmental problems like the Urban Heat Island Effect and combined sewer overflow events. This is particularly true in urban areas where roofs constitute a large percentage of the overall surface area. In New York City, for example, roofs constitute 11.5% of the total area, or roughly 944.3 billion square feet.

The New York City Department of Design and Construction, as the construction arm of the New York City government, is responsible for many of those roofs, and manages an annual budget of approximately 500 million dollars for building construction and renovation. Additionally, DDC is responsible for guiding City projects toward better, greener buildings within limited construction budgets. Accordingly, the cool and green roof strategies in this report are discussed primarily in terms of their environmental effectiveness – would this be the best way to allocate "green strategy" project money for the most environmental benefits?

This manual attempts to provide DDC's managers and consultants with theoretical, historical, and technical information on different roofing strategies so they can make well-informed decisions on a project basis. In order to more accurately discuss the thermal behavior of cool and green roofs, we hired Flack and Kurtz, Inc. and SHADE Consulting, LLC to perform energy simulations of a range of different roofs on a hypothetical DDC building in NYC; the results included in this manual indicate that, when considered at the scale of a single building, both cool and green roofs have a very modest impact on building energy consumption. However, when considered as a strategy to help reduce the Urban Heat Island Effect, the reduction in energy use is more dramatic and therefore supports the claim that the added cost for a cool roof, though not for a green roof, is justified in terms of energy savings. This conclusion is supported by a report entitled "Mitigating New York City's Heat Island with Urban Forestry", recently published by the New York State Energy Research and Development Authority (NYSERDA), and by the DDC analysis included as an Appendix to this report.

The research provided here by Gruzen Samton Architects, LLP also indicates that, in addition to green roofs not being very cost-effective as a way to save energy, there is currently insufficient data available specific to NYC on the relative cost and feasibility of including green roofs in the city's plans for stormwater and air quality management. Though certainly the question of whether green roofs have a role to play for NYC in these other areas warrants further study, it is already clear that various types of green roofs often appeal to building occupants and the surrounding neighborhood when conceived and designed as amenities that enhance the livability of the city. Examples of such amenities might include accessible roof gardens, views of planted roofs from adjacent taller buildings, and even habitat for wildlife, with the most appropriate application and design being determined by program, budget, and the physical context of a particular project.

Office of Sustainable Design
NYC Department of Design and Construction
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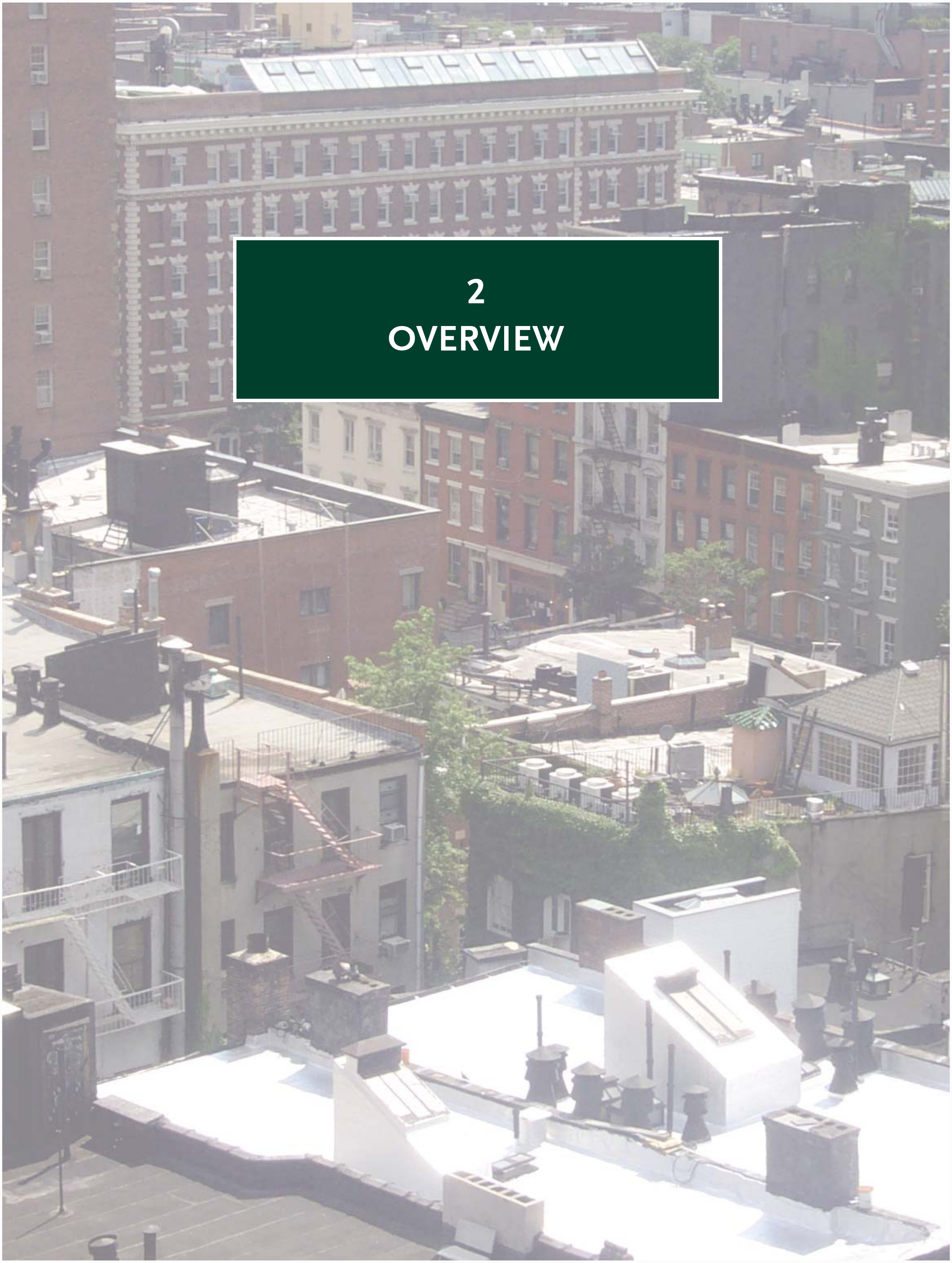

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OVERVIEW

OVERVIEW

New York City has almost one billion square feet of roof area, and people are starting to pay attention to it. Increasingly, cool and green roofing strategies are proposed as solutions to a number of endemic urban problems, ranging from high energy bills to the Urban Heat Island Effect to excess stormwater runoff. Although research and monitoring is underway in the Northeast, the quantitative results have not caught up with the claims for cost-effectiveness and performance in energy savings and stormwater reduction. To date, most of the research and evaluation has been done in climates warmer than New York City, and/or with buildings that have not had to conform to energy codes and other requirements equivalent to that of New York State. This manual looks at the research to date and the potential for cool and green roofs, from the point of view of NYC's Department of Design and Construction and their project profile.

Our intention here is to offer some insight into the many issues related to the use of cool and green roofs in New York City, while also providing DDC project managers and consultants with a basic manual on their implementation. In this manual, we discuss in-depth a number of cool and green strategies, consider the practicality of using them on DDC's construction projects, and evaluate whether they improve the local environmental performance of a typical DDC building. Energy modeling projected individual building energy cost savings, using project types and utility rates applicable to City projects. The cumulative environmental impact of citywide cool and green roofing is considered in context with other potential strategies to cool off the city.

Our findings on energy savings, as demonstrated by the energy evaluation presented in the next chapter, show that neither cool roofs nor green roofs are particularly cost effective strategies for energy-use reduction in new or existing buildings in New York City. However, when combined with other Urban Heat Island mitigation strategies, the case for cool roofs– particularly on existing buildings– becomes far more compelling.

ENVIRONMENTAL IMPACTS OF HOT, DARK ROOFS

On a hot, sunny summer day, the temperature of a black roof surface can be about 90° F above the ambient air temperature (ie, 180° on a 90° day). This is because non-reflective roofs absorb and retain solar energy as heat, which contributes not only to a hotter roof, but also to uneven thermal expansion/contraction and aging of the roof, and sometimes to heat gain within the rest of the building. The top floors of the building underneath can be heated up by the hot roof, and cause either discomfort for the building inhabitants or increased local cooling loads–particularly in older buildings, which tend to have less insulation. Because of the heat stored in non-reflective roofs, both the city and individual buildings stay hotter and begin the summer day at a temperature much higher than that of the suburbs.

It's not just your imagination: the city really is warmer than the surrounding countryside. In the summer, average temperatures in the largest cities can range from 5° to 10° warmer. This phenomenon, known as the Urban Heat Island Effect, results from several factors in addition to dark roofs–chiefly the relative dearth of vegetation in cities and the preponderance of dark surfaces on roads and parking areas. All of these factors work together to compound the problem: dark surfaces absorb heat, and a lack of vegetation deprives us of the natural cooling that living plants provide.

In cities, there are vast areas of dark asphalt roofs and roadways absorbing heat and amplifying heat gain on the macro-scale, which can affect the very climate of cities and metropolitan areas. Not only do cities as a whole become hotter, the wind patterns can change, and there is evidence that cities can attract or even cause thunderstorms.[1]

Increased temperatures in cities have been recorded for almost 200 years. In 1807, Luke Howard, an amateur meteorologist, began comparing the temperatures of various sites in London with those several

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[1] *See: http://www.nytimes.com/library/national/science/081500sci-environ-climate.html*

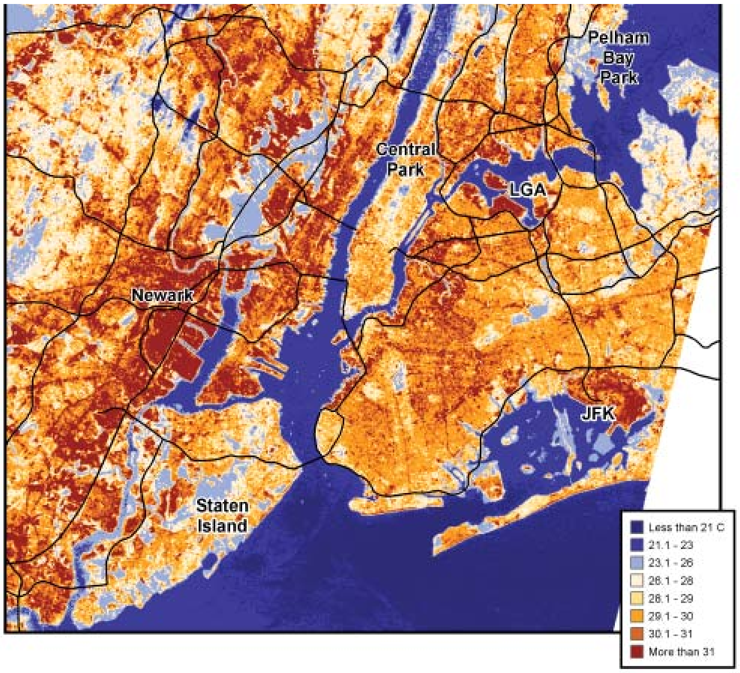
miles outside the city. In 1818, he published a book, *The Climate of London*, which concluded that London is “always warmer than the country, the average excess of its temperature being 1.579 degrees.” As cities have grown in density and scale, this temperature differential has undergone a marked increase.

Besides making us uncomfortable, the added heat damages the environment in the following ways:

- Hotter roofs and higher air temperatures mean hotter buildings and/or more energy consumed by air conditioning. In addition, the heat rejected by air conditioning adds further to the heat generated in the city.
- Increased consumption caused by the Urban Heat Island Effect occurs during peaks of energy consumption. This is a real problem in New York City, where a shortage of peak capacity may result in more frequent blackouts.
- A hotter city means more air pollution. Not only does increased heat cause more energy consumption because of cooling loads, but the energy production adds pollutants such as nitrous oxides, sulphur dioxide and carbon dioxide to the air. On the peak summer days, it also taxes the utility companies, pulling online the older, less efficient power plants. Resulting emissions of greenhouse gases contribute to local air pollution and global warming.
- Pollution increases with the ambient outdoor temperature. Ground level ozone (smog), a health hazard, is produced when pollutants such as nitrous oxide and volatile organic compounds combine photochemically in the presence of sunlight and heat. This occurs much more readily at the higher temperatures.
- Urban heat can even cause deaths. A 1995 heat-wave in Chicago is estimated to have killed over 700 people– over twice as many as perished in the infamous Chicago Fire of 1871. Many of those who died were low-income persons who did not have air-conditioners and were unable to protect themselves from the ambient temperatures. Even more shocking was the European heat wave of August 2003, which is estimated to have claimed the lives of 35,000 people, with over 14,000 dying in France alone.

IMPACTS ON NYC—CONSIDERING GLOBAL CLIMATE CHANGE

New York City is undeniably experiencing a gradual increase in temperature, thanks not only to the Urban Heat Island Effect but also to global climate change caused by a century and a half of increasing greenhouse gas emissions from industrialized nations. According to a 2001 study by the Columbia Earth Institute for the U.S. Global Change Research Program, *Climate*



Thermal Imaging of NYC
Cox, J., M. Chopping, S. Hodges, L. Parshall, C. Rosenzweig, and W.D. Solecki. 2004. Urban Heat Island and the Built Environment: Case Study of New York City. Association of American Geographers. March, 2004. Philadelphia, PA.

Change and a Global City, there has been an increase of approximately 2°F in the New York region since 1900. Regional rature rise is predicted to accelerate over the 21st century, with warming projected to range from 1.7°F to 3.5°F in the 2020s.

A few degrees may seem insignificant. However, if this trend is not arrested, the consequences are grim and far-reaching. The effects of global climate change will be most painfully felt in the planet's tropical climates and coastal communities. NYC lies in a temperate climate zone; however, with hundreds of miles of shoreline and a projected 9.1 million inhabitants by 2030, it is certainly one of the world's largest coastal communities, and therefore vulnerable. Sea levels along the New York coast could rise as much as 5 inches by the 2030s, making flooding and inundation of all low-lying areas of NYC–in particular lower Manhattan, Southern Brooklyn and Queens, and Staten Island–more likely during major storm events, causing damage to property as well as transportation and other vital urban infrastructure. The city's water supply would suffer in terms of both quality and quantity, and the total energy demand would rise in order to meet intensified summer cooling. Additionally, the number of summer days above 90°F could rise from 14 days in 1997-1998 to between 40-89 days by the 2080s, increasing the number of heat-related deaths, expanding habitat and population of disease-carrying insects and exacerbating asthma-inducing pollution.[1]

ROOFS AND DDC

Cool roofs are required on DDC projects.

DDC's Consultant Guide requires low slope roofs to have a reflectance of 0.65, and DDC recommends meeting the emittance requirements of California Title 24 or LEED.

NYC's New Construction Codes require white or Energy Star® roofing on low-slope roofs. (effective July 2008)

Green roofs are permitted by the New Construction Code, and PLANYC 2030 proposes to encourage them with a tax incentive. DDC considers green roofs on a project-by-project basis – see text.

WHAT IS TO BE DONE?

The threat of climate change demands an immediate, global reduction of greenhouse gas emissions, requiring action at every governmental level, from national to municipal. New York City has taken up the challenge with a comprehensive sustainability plan, PlaNYC 2030 (page 2.5). Like every successful campaign, it is made up of incremental, doable actions.

So what can DDC and its consultant teams do? Because buildings and paved surfaces are the major contributors to the Urban Heat Island Effect, each project has an incremental effect on the temperature and livability of the City. We can replace dark surfaces with lighter, more reflective, ones and reintroduce vegetation where possible, and of course construct more energy efficient buildings. As with many more sustainable approaches, the simplest and most obvious solutions can be informed by the intuitive principles and practices of age-old communities and dwellings.

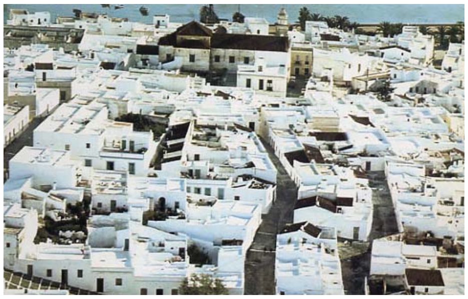


photo: Ruben Tomasov

Cool Surfaces. We know that lighter colors keep us cool, since they reflect heat, while darker colors tend to keep us warmer, and so we wear lighter colored clothes in the summer than in the winter. Traditional cultures have exploited this phenomenon – think of the white-washed villages of the Greek islands, where every part of the village, from the walls, to the roofs, to the streets, are painted uniformly white to reflect the scorching rays of the summer sun.

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[1] *PlaNYC, A Greener, Greater New York; 2007*

In more scientific terms, we can discuss the cool, bright, white surfaces of Mediterranean villages in terms of two important and related surface properties: solar reflectance and thermal emittance. Reflectance, also known as albedo, is a percentage scale expressing the ability of a surface to reflect the sun's rays, rather than absorb the solar energy as heat. The ability of the material to then radiate away any energy absorbed as heat back into the atmosphere, or cool off, can be expressed by emittance, also a percentage scale. If we begin to use materials and surfaces with high reflectance and emissivity, we can reflect and radiate away some of the trapped solar energy that is heating our city. On the same hot 90° F degree day previously mentioned, a bright white smooth roof will only be about 15° above the air temperature, rather than 90° F. The Heat Island Group at Lawrence Berkeley Laboratories, lead by Hashem Akbari, has done studies indicating that if dark roofs were replaced by highly reflective roofs, throughout an entire metropolitan area, the urban heat island effect could be reduced by 2-3° F.

Planting. Also, we have all experienced how much cooler it is in a grove of trees than in a parking lot, and how much hotter it is to walk barefoot on asphalt pavement than on a lawn. Plants provide natural cooling in several ways – by providing shade, by utilizing the sun's energy in photosynthesis, and, most importantly, by evapotranspiration, which is similar to perspiration. When plants transpire, they turn water into vapor, dissipating the latent heat of vaporization and providing cooling. This process can dissipate a lot of heat; A mature tree provides approximately three tons of free cooling through transpiration. Green roofs offer an opportunity to introduce vegetation to a large number of expansive surfaces, many of which would otherwise be dark, heat absorbing and unused. The Organization for Landscape and Urban Greenery Technology Development estimates that if half the roofs in Tokyo were planted with gardens, the hottest summer temperatures would fall by 1.5 ° F.

TABLE 1: ROOF TEMPERATURE RISE ABOVE AIR TEMPERATURE — FULL SUN/NO WIND

MATERIAL	TEMPERATURE RISE
Bright white smooth	+15° F
Rough white surface	+35° F
Medium grey	+52° F
Built-up Roofing with Gravel	+61-83° F
Black Material	+90° F

Source: LBNL Cool Roofing Materials Database

So What About the Winter? In New York it might seem that the disadvantages of a cool roof in winter would offset the advantages in the summer. This has been found to be the case in very cold climates, such as Minneapolis, and climates in which the summers are cloudy and cool, such as Seattle. In New York City, there is a winter penalty, but the benefits in summer outweigh it. Lawrence Berkeley Laboratory's Heat Island Group conducted a study in 1997 that examined the energy conservation effect of changing to white roofs in 11 US Cities.[2] Lawrence Berkeley National Laboratory (LBNL) used computer modeling that considered factors including cooling degree days, sunny/cloudy days, lost heat gain in winter, typical roof color currently, local electricity costs, etc. While it showed much greater savings in sunbelt cities like LA and Phoenix, the study projected cost savings for NYC with cool roof systems. Specific to the winter penalty, LBNL estimated that the solar absorption effect is less in December than June, because the days are shorter, the sun is lower in the sky and the winter is much cloudier. Also, the energy costs of air conditioning (mostly electric, and at times of peak demand) and heating (mostly gas or oil) factored into the analysis. In addition to energy conservation, the other summer impacts of pollution and ozone production are greatly reduced in the winter.

CONSIDERING COOL SOLUTIONS

Our analysis of the possible solutions cool and green roofs might offer was on the building-specific impact. In order to determine how much energy they would save per building in New York City's climate, we ran an energy model of a new, typical-for-DDC building, varying the reflective and emissive properties of the roof to determine the annual energy savings.

Cool Roofs. We found that for new city government buildings, none of the cool roofs analyzed would pay for themselves in energy savings within the lifespan of the roof, given the government's relatively low energy rates, and assuming a well-insulated, and efficient building. (One exception is a metal roof, for which there is typically no upcharge for a light color.) For older, less efficient private structures paying ConEd rates, simple paybacks for cool roofs are between five to fifteen years for individual buildings – a more justifiable expenditure. The cost-effectiveness of cool roofs becomes truly compelling when the savings on individual buildings are added to savings generated by the ability of many cool roofs to lower the overall temperature of the whole city (See below: cumulative impacts). In addition, cool roofs can extend the life of the roof membrane by decreasing thermal cycling and protecting them from ultraviolet radiation. For these reasons, DDC is requiring cool roofs on all new projects and on all re-roofing projects (see page 2.8).

Green Roofs. We also found that, per unit area, green roofs save over twice the energy as cool roofs, but since their cost is more than an order of magnitude higher, their paybacks are extremely long. For a new city government building paying low rates, the simple energy payback period is in the hundreds of years, and even for older private buildings paying higher rates, the simple payback period is still in the range of 70 years. If implemented on a large scale, green roofs, like cool roofs, can contribute to an overall reduction in the city's temperature, but their combined effect on individual buildings and citywide savings is not sufficiently cost-effective to recommend them for general City project use as an energy-efficiency measure.


photo: Mathews Nielsen Landscape Architects P.C.

Tribeca Green, Manhattan

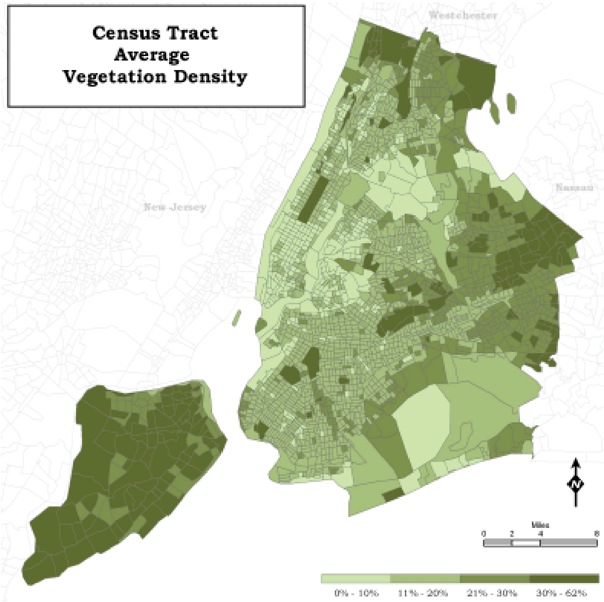
Cumulative Impacts. It has been shown that introducing lighter, more reflective surfaces and/or more greenery can mitigate heat build-up on the scale of individual buildings. But how cost-effective would it be to reduce the ambient air temperature and cooling load of the City of New York by lightening or greening the city on a large scale?

Each more reflective and greener building contributes to the City's overall ability to mitigate NYC's Urban Heat Island Effect. The New York State Energy Research Development Authority (NYSERDA), recently published a study, Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, and Light Surfaces. The study used a regional climate model to analyze the cost effectiveness of various strategies for reducing the City's air temperature. They found that a combined strategy of vegetation, especially street trees, and lighter surfaces on roof and pavements is most effective overall. Light surfaces, light roofs and street trees were found to be the most cost-effective strategies per degree of temperature reduction.

WHAT'S HAPPENING IN NEW YORK

PlaNYC 2030. New York City set forth a comprehensive sustainability plan in 2007. Called PlaNYC 2030, it aims to reduce the City's greenhouse gas footprint, committing to reducing citywide carbon emissions by 30% below 2005 levels by the year 2030 with a series of initiatives, such as reduced City energy consumption and use of cleaner energy. The plan addresses change and proposes steps in six categories, land, water, transportation, energy, air and climate change.

PlaNYC's greenhouse gas reduction goal was conceived with vision on a global scale, and implementation on a smaller scale, with specific initiatives that create an integrated strategy. Addressing the Heat Island Effect with lighter surfaces on roofs and paving, and the introduction of more overall planting are among the implementation plans. White or reflective roofs will be required in the New Construction Codes to take effect in July 2008.



New York Ecological Infrastructure Study
Imaging used as an analysis tool in a study exploring the potential of vegetated roofs to address environmental issues.

Cox, J., M. Chopping, S. Hodges, L. Parshall, C. Rosenzweig, and W.D. Solecki. 2004. Urban Heat Island and the Built Environment: Case Study of New York City. Association of American Geographers. March, 2004. Philadelphia, PA.

PlaNYC encourages the installation of green roofs as a measure to control stormwater runoff and avoid Combined Sewer Overflows (CSO). The proposed incentive is a property tax abatement to offset 35% of the installation cost of the green roof.

DDC has already incorporated cool roofs on a number of projects which meet the emittance and reflectance criteria of LEED. Among them are the Office of Emergency Management, New DOT Sunrise Yard, Glen Oaks Branch Library, and Department of Homeless Services. In addition, DDC has two current projects that incorporate green roofs – the Queens Botanical Garden and the Kingsbridge Branch Library in the Bronx.

Regional research on the Urban Heat Island Effect and ways to mitigate it have been going on for several years. A recently published study, *Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, and Light Surfaces*, is mentioned above. In addition to that study, the Earth Institute at Columbia University and NASA/Goddard Institute for Space Studies have partnered with other researchers for several projects. Among them are New York Ecological Infrastructure Study Green Roof Project (with Hunter College-CUNY, Earth Pledge and Pennsylvania State University's Center for Green Roof Research) and Climate Change and a Global City (with numerous stakeholder involvement).

Green, planted roofs are gradually appearing in New York City, sponsored by community groups, environmental organizations, institutions and private developers. Recent installations include Silvercup Studios in Long Island City, with a 35,000 square foot extensive roof, with funding assistance from the Queens Clean Air Project. Also in Long Island city is the Gratz Industries Building, with a green roof covering about three quarters of its 11,000 square foot rooftop, allowing comparative research to the non-planted portion. In the Bronx, the County Courthouse has a 10,000 square foot extensive green roof. This is the first to be managed by the NYC Department of Citywide Administration (DCAS).

Sustainable South Bronx, a community based organization to address environmental needs and policies of the South Bronx, is an advocate for green and cool roofs in New York City. They have partnered with Columbia University's Cool Cities Project, sponsored workshops and promoted green roofs on a city-wide scale.

Earth Pledge, a not-for-profit organization dedicated to sustainability, has established the Green Roofs Initiative to promote and support the development of green, vegetated rooftops in New York City. They established a Green Roof Policy Task Force to bring together city, state and federal agencies to explore the public policy issues of developing green roofs in the City. Earth Pledge has launched Greening Gotham, whose mission is to transform NYC's rooftops into a living network of meadows and gardens, by providing examples and a toolbox of implementation information. Earth Pledge is monitoring environmental effects such as temperature and stormwater retention for the green roofs at Silvercup Studios and Gratz Industries, mentioned above.

The Battery Park City Authority has issued green guidelines and prescriptive requirements for new construction in Battery Park City. For roofing on new construction, a green planted roof must be installed for 75% of the open roof area, and all other roofing must have a minimum reflectance value of 0.30. At this time, Battery Park City has the NYC's most concentrated grouping of buildings with planted roofs.

WHAT OTHER STATES AND CITIES ARE DOING

The State of California has established Title 24 standards (California Code of Regulations, Title 24, Part 6 Energy Efficiency Standards for Residential and Non-Residential Buildings) for residences and commercial buildings. Using cool roofs is an important energy efficiency compliance strategy, one of several methods of fulfilling the standards. Title 24 cites minimum reflectance and thermal emittance for different types of roofing materials. Title 24 standards are of note because they are well known and often referenced by roofing manufacturers.

The City of Chicago, Illinois has been successful in policy making for both planted and cool roofs, and was one of the first US cities to encourage planted roofs, including the roof of City Hall, and monitor their effects. Cool roof are required. For now low-sloped roofs have a minimum weathered reflectance of 25 percent, however, after December 31, 2008, all low-sloped roofs must meet or exceed Energy Star criteria. Green roofs qualify for this requirement. Chicago is working with the US EPA and DOE to assess the impacts of these roofs on Chicago's heat island.

Other cities and states are focusing on the integration of cool and/or green roofs into their building policies. There are many examples. The Georgia White Roof Amendment requires the use of additional insulation for roofing systems whose surfaces do not have test values of 75 percent or more for both solar reflectance and emissivity. A number of cities–e.g. Milwaukee, Pittsburgh, Portland, Seattle–have incorporated green roofs into their policies for stormwater control.


photo: 2004 Roofscapes, Inc.; used by permission; all rights reserved

Chicago City Hall

RELEVANCE TO NYC DEPARTMENT OF DESIGN & CONSTRUCTION

Soon we will be seeing more cool roofs in New York City–both because of increased environmental awareness and because they will be required.

DDC's Design Consultant Guide - 2003 requires that roofs have a minimum reflectivity of 0.65, based on the EPA/DOE's Energy Star® standard for low-slope roofs (most of DDC's projects have low-slope roofs). Emittance was not specified in the Guide, but DDC recommends that the roofing meet the emittance requirements of LEED or California Title 24 standards (California Code of Regulations, Title 24, Part 6, Energy Efficiency Standards for Residential and Non-Residential Buildings). Cool roofs should be used for new buildings and roof replacements. Given the results in this report, the savings of cool re-roofing of existing buildings is likely to be higher, assuming that the buildings are older and perhaps less efficient and less well insulated.

The New Construction Code, to take effect in July 2008, requires cool roofs on all projects, both new and replacement. The section (BC 1504.8) mandates roofs that are white in color or Energy Star® rated as highly reflective for a least 75% of the roof or setback surface. This applies to roofs with a slope of less that 25%, and smaller setbacks are exempted. A green roof can substitute (see BC 1507.16), as can a recreational space if any paved area has an albedo of greater than 30%.

Local Law 86 of 2005 encourages cool or green roofs, because LL86 requires many of DDC's projects to achieve a LEED rating of Certified or Silver, depending on their occupancy group, construction cost, and a number of other factors. LEED NC 2.2 devotes a point to cool and green roofs (Sustainable Sites Credit 7.2: Heat Island Effect: Roof), and the LEED cool and/or green roof criteria should be followed on all LL 86 projects pursuing this credit. Most of DDC's projects targeting LEED to date have incorporated a cool or green roof.

Green roofs offer a broader range of benefits than those of cool roofs, but their cost is much higher, leading DDC to conclude that the case for green roofs as a strategy for energy use reduction is tenuous. Because of the their cost, it is important that they not be implemented at the expense of other very effective measures to reduce building energy consumption, such as daylighting, lighting control, and more efficient mechanical systems. Similarly, at-grade landscape techniques, such as vertical green shading, permeable pavements, street trees and light colored surfaces, may offer comparable, or even greater, benefits than a green roof offers–with lower up-front investment.

The stormwater management benefits of green roofs in NYC are still under study. DDC project teams need to evaluate all possible stormwater management strategies, such as "blue" roofs, collar drains, cisterns, and other on-site retention and detention techniques, such as tanks, drywells, and others already mandated by the NYC Department of Environmental Protection. To date, DEP has not accepted green roofs in lieu of detention tanks.

The range of DDC project types is very great, so specific circumstances may make a green roof the right decision, and justify the higher cost. For example, construction costs on Riker's Island are very high, and any strategy that extends the life of a roof may be an incredibly attractive option. Current research suggests that green roofs have very long lives, so they may be appropriate in this context. Additionally, projects for which occupant stress reduction is a design priority may want to employ planting strategies, such as green roofs, in order to provide a calming connection to nature. The attraction of people to natural areas, a phenomenon known as "biophilia," is gaining credibility as a method to establish positive feelings and connections between people and their immediate environment. As it pertains to New York City, biophilia is beginning to play a part in the current administration's long-term goal to make densely populated NYC more liveable.

The benefits green roofs offer as usable outdoor space may also make a compelling argument. An intensive green roof offers the potential for creating protected outdoor space for DDC building types, such as libraries, cultural institutions, 24-hour service agencies and health care facilities–space that may not be available at ground level.

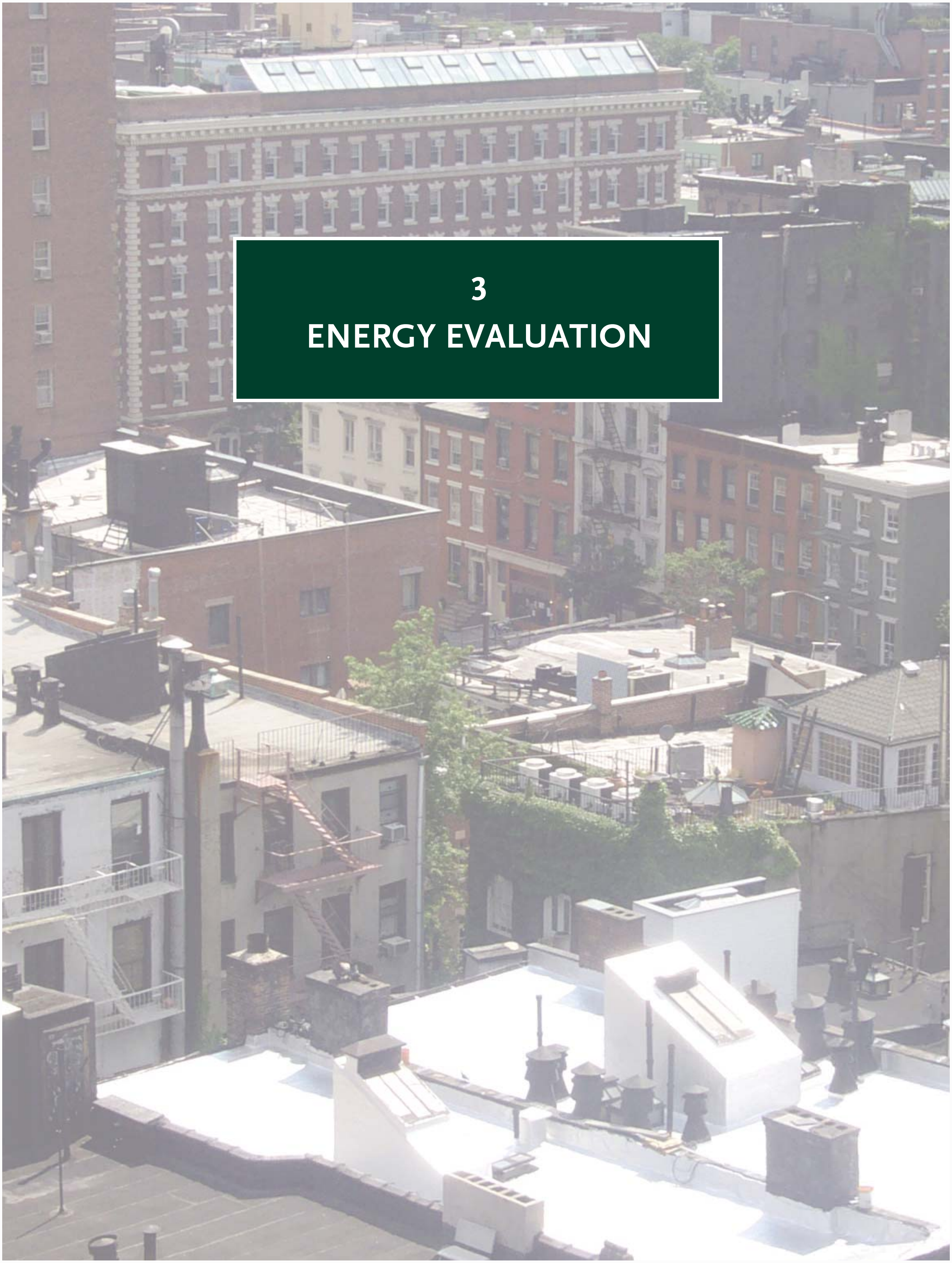
In some DDC projects, such as the Queens Botanical Garden shown on the next page, a green roof makes a lot of sense. Here, a semi-intensive green roof over a sunken auditorium, slopes up from grade in a poetic gesture that advertises the ecological mission of the Garden, while providing an amenity to the public.

BKSK Architects LLP Rendering: Brooklyn Digital Foundry

Queens Botanical Garden

3

ENERGY EVALUATION



ENERGY EVALUATION

This energy evaluation was prepared in 2004, using both the roofing costs and DDC's energy costs at that time. In 2007, the time of this report's issuance, the general conclusions remain the same. The basic costs parameters, both roofs and energy, were reviewed for consistency, although the computer energy modeling was not rerun.

The degree to which cool and green roofs save energy and money for individual building owners is largely situation-specific. To date, most of the research and evaluation has been done in climates warmer than New York City, and with buildings that have not had to conform to energy codes equivalent to that of New York State.

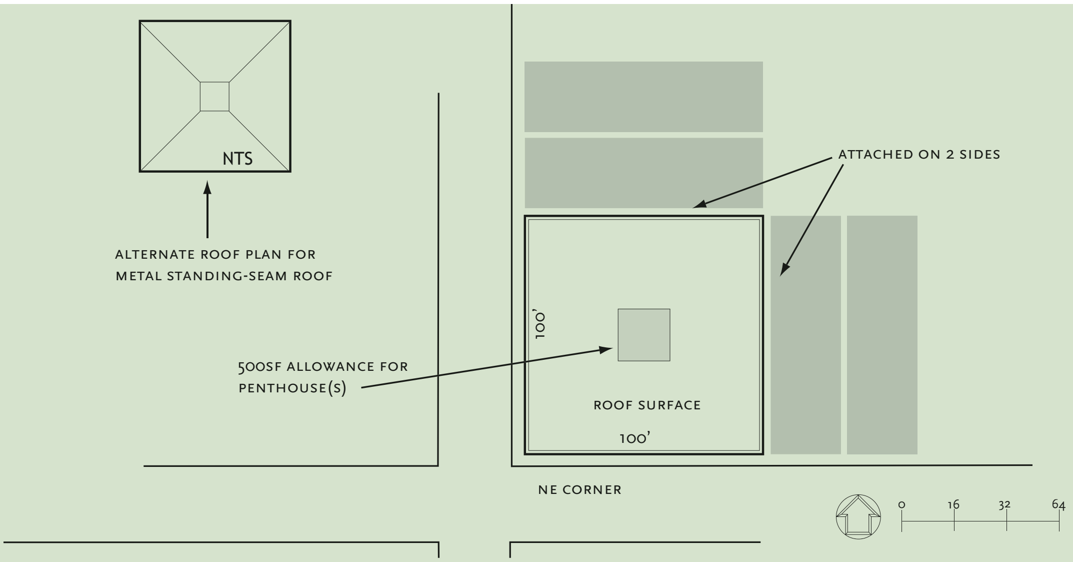
This energy analysis for typical and proposed New York City roofing strategies, modeled the energy cost savings as a basis for comparison. We were surprised to find that in NYC, on a single building basis and not accounting for any reduction in the citywide Urban Heat Island Effect, the incremental cost of cool roofs relative to conventional dark roofs does not pay for itself on new buildings–the calculated payback period exceeds the life of the roof in almost every instance. Only on older buildings, those poorly insulated and inefficient, do cool roofs pay for themselves. Among the existing buildings modeled, an immediate payback was achieved by upgrading a dark metal roof with a light or "cool" coating, and the replacement of a black membrane roof on an older building with a white membrane paid for itself in roughly five years (using Con-Ed energy rates).

Another finding was that cool white membranes and coatings significantly outperform currently popular strategies, like aluminum coatings and white cap sheets, with respect to energy cost savings and payback. This is primarily due to the increased emittance of cool roofs. Still, the long payback periods and overall findings seem at first to demonstrate that it may not make sense for DDC to use cool roofs on a per-building basis. The case only becomes truly compelling when the above savings are combined with the mitigating impact cool roofs would have on the Urban Heat Island Effect – something that benefits the City at large. When one takes into account their cumulative impact, even the cool roofs on the more efficient new buildings appear to pay for themselves in roughly six years in energy savings alone (see Urban Heat Island Mitigation in the Chapter 6).

The study did determine that cool and green roofs substantially reduce the temperature of roof surfaces, approximately 20% in the case of the aged-white roof and 38% in the case of the planted green roof (both July). Reduced surface temperatures have been shown to prolong the life of the roof membrane and reduce the heat transferred through the roof membrane into the building. Also, it can be inferred that substantially reduced rooftop temperatures will lower the temperature of the air entering rooftop intake units, reducing the local cooling load. Although not taken into account here, we recommend this potential effect be modeled in further investigations.

THE ENERGY MODEL

A simulation of the potential energy cost savings for these typical types of reflective roofs was conducted using the DOE-2 building energy computer simulation program, with E-QUEST interface. DOE-2, developed under the sponsorship of the U.S. Department of Energy, is an energy analysis software tool that calculates the hour-by-hour energy use of a building, given detailed information on the building's location, construction, operation and HVAC systems. The DOE-2 computer model used average New York City weather data, including solar incidence, to simulate building systems operation, energy demand and consumption for an entire year. For the extensive green roof, a computer algorithm developed by SHADE Consulting was used with the DOE-2 base data to model the potential savings from a planted roof. This factored in the shading, insulation and evapotranspiration of the foliage, planting medium and drainage layer.



PLAN OF ROOF

SIZE:	20,000 sf on 2 floors + 500 sf Penthouse(s) - elevator/stairs
LOCATION:	NE Corner; Attached on 2 sides: No shadows from neighboring roofs
OCCUPANCY:	24 hours/day; 7 days/week Day shift = 100% of rooms occupied; Evening shift =67%; Night shift =33%
BASE ROOF:	(Typical for DDC projects) 4-Ply built up roofing over tapered rigid insulation, over 5" (total) lightweight concrete slab, on 1½" composite deck Reflectance: 0.06 Emittance : 0.90 (Initial value) Slope on Metal Roof: 3:12 (With attic)
WALL SECTION:	(Typical for DDC projects) 8"x8" bricking facing, over 1" cavity + 2" rigid insulation, over 8" CMU at the interior Floor-to-Floor Height: 13'6"
WINDOWS:	25%; Double-glazed w/ thermal breaks; Low-E glass
LIGHTING:	1.3 Watts/sf during the day shift; Reduced proportionally during other shifts
EQUIPMENT:	Typical office plug load; No special equipment
HEATING/COOLING	Temperatures = 70 degrees F Heating / 75 degrees F Cooling VAV System; perimeter radiation; Indoor equipment with cooling tower; Gas-fired hot water heating with boiler.; Air-side economizer
NYC DDC'S FIRM GAS RATE	= $0.90 per Therm in 2004
NYPA ELECTRICAL RATES IN 2004 =	General Buildings (less than 1500 kW) both summer and winter $0.039/kwh and $20/kw demand charge monthly General Buildings (more than 1500 kW) Summer = $0.04217/kwh and $30.56/kw demand charge monthly Winter = $0.04217/kwh and $10.84/kw demand charge monthly

BUILDING

The “typical” building used in the simulations is similar to many that DDC constructs for New York City Agencies. The simple building modeled is 20,000 square feet on two floors, and is assumed to meet the 2002 New York State energy code – see the inset for characteristics. The assumed operating hours are 24 hours per day, 7 days per week. Similar occupancy is found in many City agency buildings, including shelters, police and fire stations.

ROOFS

Six roof types were compared to a base case built-up roof: white coating or white membrane; aluminum coating (non-fibered); white granular surface; white gravel ballast; cool sloped metal roof; and an extensive green planted roof. Of these, only the white coating/ white membrane and cool sloped metal roof meet the EnergyStar™ requirements. Other light roof finishes with insufficient reflectivity to qualify for EnergyStar™, such as aluminum coating and white granular cap sheet, were also analyzed, because they are commonly used in NYC, and DDC wanted to understand their effectiveness.

The analysis modeled aged reflectance values, rather than initial reflectances, in order to take into account the detrimental effects due to weathering and accumulation of dirt on the roof over a three year period. Aged reflectance values were achieved by reducing initial reflectance values (taken from the Lawrence Berkeley National Laboratory Cool Roofing Material Database) by a standard 35% for membranes and coatings, and 5% for the metal roof, as per two study reports from the Oakridge National Laboratory, *Long Term Reflective Performance of Roof Membranes, and Cool Metal Roofing Tested for Energy Efficiency and Sustainability*. Emittance values were not changed, because the Oakridge studies showed little diminishment over time. It was assumed that DDC’s roofs will not be washed.

ENERGY SAVINGS FOR NEW BUILDINGS

For all roof types, very modest annual energy savings (again not accounting for reduction in the urban heat effect) were predicted by both the DOE-2 energy simulation and the SHADE Consulting Q-Calc™ energy analysis tool. For the reflective group, the benefits vary by roof type, but appear to be optimized by the white coating/white membrane roof, i.e. the Energy Star® labeled cool roofs – at an annual net savings of approximately $0.01/sq.ft. of roof. Other currently popular roof finishes, such as aluminum coated or white granular cap sheet, showed even less savings: from $0.003 to $0.004/ sq.ft. annually. From this we see that these popular strategies are much less affective than the new generation of Energy Star® roof products. For all the reflective roofs, the cooling savings are offset by a slight penalty in heating cost due to the loss of solar heat gain in the winter. For the extensive green roof, the annual net savings were approximately $0.022/sq.ft. of roof. The increased savings can be attributed to greater reduction of summer heat load, and to a slight energy savings in winter instead of a penalty.

The energy savings from the model were less than we would have anticipated from the research and articles currently available. Several factors help explain the results:

- The modeled building was assumed to be new construction complying with New York State’s Energy Conservation Construction Code and ASHRAE 90.1-1999, e.g. the building envelope was well insulated, the HVAC systems were efficient and used cool ambient air for free cooling (economizer cycle).
- The energy rates used are based upon New York Power Authority (NYPA) rates contracted with the City of New York. The 2004 NYPA rates averaged $0.09/kwh including demand charges. Comparable rates for other NYC commercial utility customers can average twice that rate. (Typical ConEdison commercial rates were used for the variations on Table 5.)
- An aged reflectance was used rather than initial reflectance. Studies by the Oak Ridge National Laboratory have shown that reflectance can be mostly restored by washing the roof, but DDC thought that washing would be unlikely. However, if agencies could commit to roof washing, their energy savings would increase–the DOE calculator (see below) shows a proportional increase in savings when the 35% reduction in reflectance is restored. Washing the roof can be done by building maintenance staff, following the manufacturer’s procedures.

The modeling results were cross-checked using an online calculator developed by the U.S. Department of Energy, because the calculated energy savings were substantially lower than generalized estimates by others of $0.05 to $0.10 per square foot. The DOE Cool Roof Calculator developed by the Oak Ridge National Laboratory was used because it can factor in a demand charge for peak monthly load. (See Resources for web site.) When the characteristics of the modeled building were input into these models, results similar to those determined by the DOE-2 runs were obtained. (Note: the suggested values for equipment efficiencies in the DOE calculator are substantially lower than what new construction under the NYS energy code would allow.)

TABLE 5: REFLECTANCES AND ENERGY SAVINGS OF MODELED ROOF TYPES

2004 costs for both roofing and energy (both have increased in 2007, but the basic conclusions remain the same)

ROOF TYPE	NEW DDC BUILDING					ESTIMATED SAVINGS[1] FOR VARIATIONS[2]		
	SOLAR REFLECTIVE INDEX	EMITTANCE	INITIAL REFLECTANCE	AGED REFLECTANCE	ANNUAL SAVINGS[1]	NEW BLDG CON ED RATES	OLDER BLDG DDC RATES	OLDER BLDG CON ED RATES
Built-Up Roof	-1	0.90	0.06	0.06[4]	base case	base case	base case	base case
White roof coating or membrane	79-107	0.90	0.80	0.52	$ 0.01	$ 0.028	$ 0.028	$ 0.067
Aluminum Coating (fibered)	43-48	0.43	0.54	0.35	$ 0.003	$ 0.006	$0.009	$ 0.021
White Granular	28	0.92	0.26	0.17	$ 0.003	$ 0.007	$ 0.01	$ 0.023
White Gravel	37	0.90	0.34	0.22	$ 0.004	$ 0.01	$ 0.013	$ 0.029
Metal Standing Seam (green coating)	NA	0.90	0.34	0.32	$ 0.002	$ 0.013	$ 0.015	$ 0.039
Green Extensive[3]	NA	NA	NA	NA	$ 0.023	±$0.05	±$0.06	±$0.15

[1] *All savings are shown in Dollars per square foot of roof area.*

[2] *Variations for cool roofs were estimated using supplemental DOE-2 runs, assuming Con Edison rates (June 2004) for a commercial building of similar size, and construction/HVAC systems typical in 1970-1980's.*

[3] *Green roof variations were estimated.*

[4] *There is some evidence that build up roofing reflectance increases with age.*

ENERGY SAVINGS RESULTS FOR OLDER BUILDINGS

Since New York is predominantly an older city, many of its buildings do not have the efficient equipment and degree of insulation that is now required by more stringent recent energy codes. Many of DDC's reroofing projects fall into this category, so the analysis also included computer simulations for a hypothetical building from the 1970's to 1980's. Finally, for the general edification of NYC building owners, we modeled the impact of cool and green roofs on typical NYC commercial buildings that pay higher ConEd rates, looking both at old and new buildings. The results are summarized in Table 5.

From the chart, we see that annual savings from cool and green roofs are two to three times as high in older DDC buildings than in new ones. Also, commercial buildings paying ConEd rates will accrue two to three times the savings of similar DDC buildings that pay lower NYPA rates. Thus, older NYC commercial buildings will accrue roughly seven times the savings as new, energy-code compliant DDC buildings–roughly $0.067 per square foot annually for an Energy Star® roof. This matches the general rule of thumb that annual energy savings should be in the $0.05 to $0.10 per square foot range.

TABLE 6: UPGRADE COST ANAYLSIS FOR DDC COOL AND GREEN ROOFS

2004 costs for both roofing and energy (both have increased in 2007, but the basic conclusions remain the same) *Construction costs are in June 2004 dollars, stated in trade costs. See description below.*

ROOFING TYPE			NEW DDC CONSTRUCTION		OLDER DDC BUILDINGS	
TRADITIONAL	"COOL" VERSION	COST DIFFERENTIAL	ANNUAL SAVINGS[2,3]	SIMPLE PAYBACK PERIOD[5]	ANNUAL SAVINGS	SIMPLE PAYBACK PERIOD
4-Ply Built-Up Roof $12.50/sf	Top white mineral cap $13.30/sf	$0.80	$0.003	> roof life (250 yrs)[6]	$0.01	> roof life (80 yrs)[6]
	With white coating $13.50/sf	$1.00	$0.01	> roof life (100 yrs)[6]	$0.028	> roof life (35 years)[6]
	With aluminum coating $13.30/sf	$0.80	$0.003	> roof life (250 yrs)[6]	$0.009	> roof life (85 years)[6]
Built-up w/ grey gravel $12.75/sf	With white marble ballast $13.25/sf	$0.50	$0.004	> roof life (120 yrs)[6]	$0.013	> roof life (30 yrs)[6]
EPDM –black membrane $17.20/sf	EPDM – white membrane $17.50/sf	$0.30	$0.01	> roof life (30 yrs)[6]	$0.028	Appx. 10 years older bldg @ConEd rates - 5 yrs
Modified bitumen, black $13.30/sf	White mineral cap sheet $14.10/sf	$0.80	$0.003	> roof life (250 yrs)[6]	$0.01	> roof life (80 yrs)[6]
Metal, dark color $25.00/sf	Light or "cool" coating $25.00/sf	$0	$0.002	Immediate (0 yrs)	$0.015	Immediate (0 yrs)[6]
Membrane	Extensive green roof $20-25/sf (Intensive $35 +)	$8-12 [4]	$0.023	> roof life (350+ yrs)[6]	±$0.06	> roof life (130 yrs)[6]

2 New buildings are designed to meet the 2002 energy code. Energy savings as calculated for DDC, using NYPA rates. Typical commercial ConEd rates are higher.

3 Annual energy savings for all roof types were analyzed against a black built-up roof.

4 Green roof can vary significantly, depending on soil depth, plants, features and subcontractor arrangement

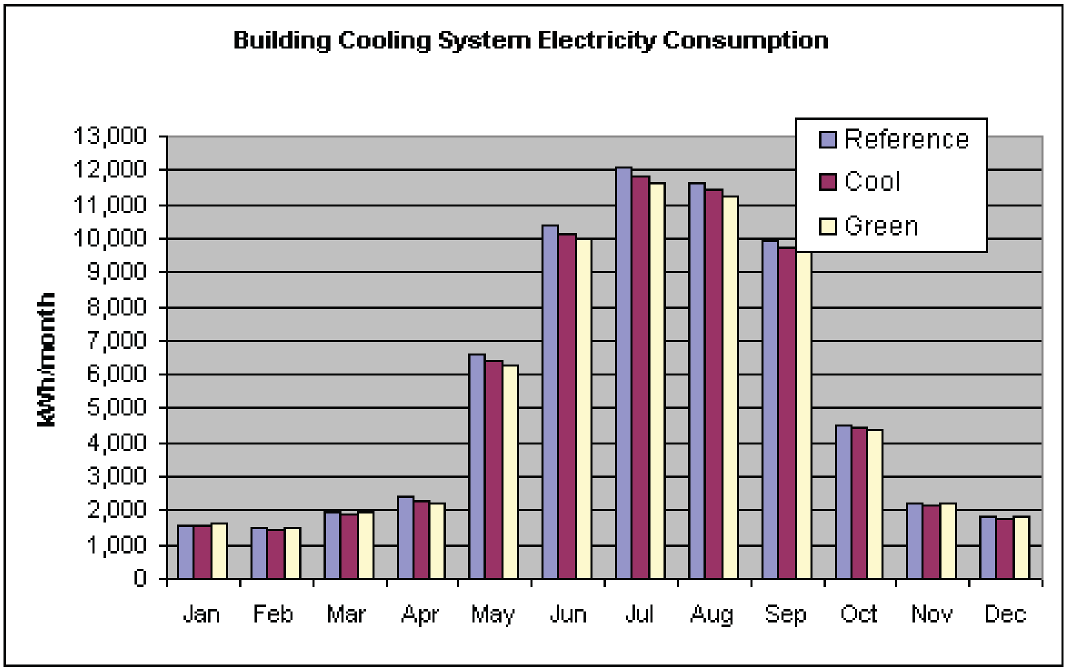
5 Simple payback of inital roof cost compared to energy savings. Maintenance and other costs are not included.

6 Years shown are for comparison only. As simple payback, the rising cost of energy is not included, which distorts these large numbers. For example, at 3% rise per year, energy costs would double in 24 years- about the life of a roof.

COST ANALYSIS

Comparative construction costs were estimated for the roof finishes used in the energy modeling. Because roofing decisions are based on many factors other than "coolness", comparisons and payback estimates are shown by roof type, white membrane, built-up etc. The cost to "upgrade" to a cool roof was estimated for each roof- type, for example, the cost premium to add a white coating to a built-up roof. This upgrade cost, and the energy savings, were used to determine the payback period.

- The estimated costs are in June 2004 dollars, and stated in trade costs.
- Installed cost would add 5-30% to the trade costs, and would include contractor general conditions, overhead and profit, special conditions. Range reflects project-specific variables.
- Pricing is based on NYC union installation.
- Estimates include insulation and flashing. Estimate for green roof is for the total roof, including insulation, membrane, system and plants.
- Estimates are for initial construction costs only. For a 20 year life expectancy, roof coatings should be replaced/renewed to restore their reflectance properties, although the cost for that is not included here. Typically, aluminum coatings should be renewed every five years and white acrylic coatings every ten years. Green roofs require some maintenance, at least initially.



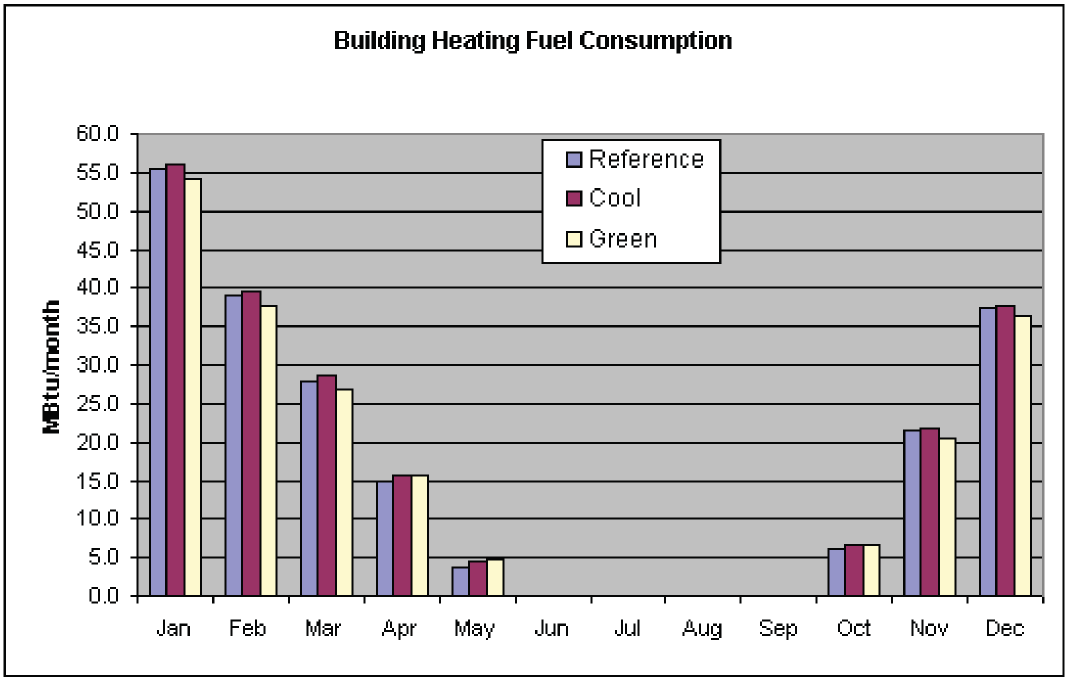


Figure 2 & 3 - Energy Consumption of Model DDC Building

Note: Cool roof is Energy Star® rated membrane or coating

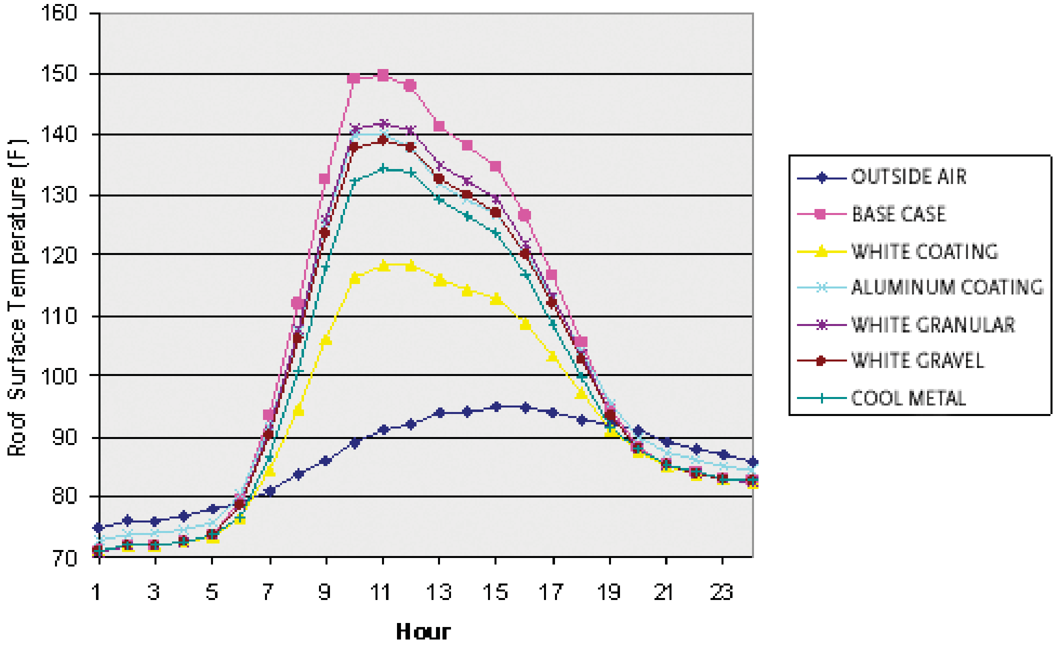
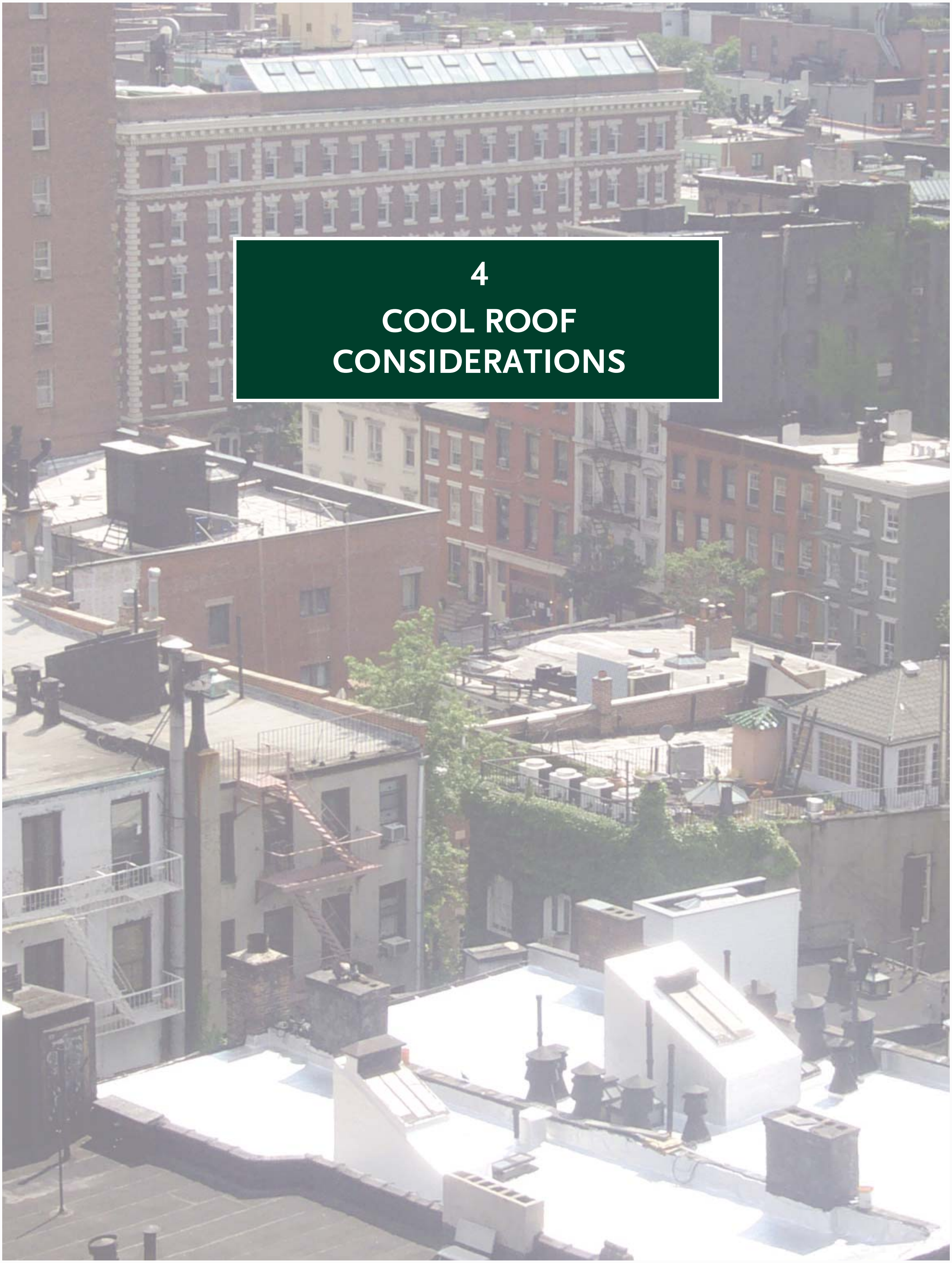


Figure 1 - Roof Surface Temperature in DDC Energy Model

*Exterior Surface Temperatures, Min ASHRAE 90.1 Insulation Peak Cooling Day Roof (Central Park TMY2, July 1)
DDC Roofing Systems Analysis*



4

COOL ROOF CONSIDERATIONS

COOL ROOF CONSIDERATIONS

Cool roofs are defined by material and surface characteristics, which reflect the sun's energy away from the roof surface. The demand for cool roof products, as well as their availability, has increased in recent years, thanks to a growing awareness of the Urban Heat Island Effect and a pressing need to conserve energy. This is especially true in the Southern states. States such as Florida and Georgia mandate a certain degree of coolness in roofs, as does the City of Chicago, while in the State of California, some utility companies offer rebates to encourage cool roofs.

White, or light, is generally thought of as the cool roof choice, but the lightest roof color is not always the coolest. Over half of the sunlight that reaches the earth's surface is not in the visible spectrum, yet can be absorbed by even light-colored roofs as heat. Highly reflective pigments for coatings, even darker ones, continue to be developed to target the infrared spectrum. As cool roof coatings evolve, understanding the different cool roof rating systems and performance standards becomes ever more important.

RATING COOL ROOFS

As described in the Overview, the coolness of a roof is contingent on two important, measurable properties: reflectance and emittance. Reflectance is the ability of the roof to reflect the sun's rays before they are absorbed as heat. Emittance is the ability of the roof to radiate any absorbed heat back into the atmosphere, or cool off. Each of these properties is quantified by ratings from 0 (no reflectance or emittance) to 1 (100% reflectance or emittance) – the higher each rating, the cooler the roof. A roof with a 0.75 reflectance and 0.9 emittance makes an excellent cool roof. However, a high reflectance rating doesn't necessarily imply a high emittance, and vice versa. This is particularly true for metal roofs; for example, an uncoated aluminum roof might have a reflectance of 0.6 and an emittance of 0.25 – hence the "Cat on a Hot Tin Roof" effect.


rendering: Scott Oliver

In order to provide a more simplified, inclusive basis for choosing a cool roof, Lawrence Berkeley National Laboratories has developed the Solar Reflectance Index (SRI). A composite index that takes into account both reflectance and emittance, the SRI can be used when some flexibility in choosing a cool roof is desired. For example, LEED-NC v2.2 evaluates the coolness of a roof based on the SRI, rather than individual reflectance and emittance. Some project specifications may also wish to call out the SRI instead, in order to allow designers some latitude in selecting a roof. Nevertheless, individual reflectance and emittance ratings should be used in all cases where a more sophisticated understanding of the ability of a surface to resist solar heat is required, such as in energy modeling.

COOL ROOF STANDARDS

There are a number of different standards for cool roofs that could be applied to DDC projects, each with varying levels stringency. DDC's 2003 Design Consultant Guide currently requires roofs to have a minimum reflectivity of 0.65, based on the EPA/DOE's Energy Star® standard for low-slope roofs (almost all DDC projects have low-slope roofs). For the 2003 Guide, emittance was not included. Based on the findings in this report, DDC may supplement their architectural design criteria for roofing with a performance standard that considers both reflectance and emittance. In addition to DDC's internal requirement, New York City will require cool roofs with the New Construction Codes to be effective in July 2008.

The California Energy Commission's Building Energy Efficiency Standards (commonly known as California Title 24) and the United States Green Building Council's Leadership in Energy and Environmental Design (LEED) Standards for New Construction consider both reflectance and emittance, and are generally regarded as the standards most contemporary with the latest strategies and technologies - LEED being the more stringent of the two. Therefore, DDC recommends that its projects not captured by Local Law 86/2005 adhere to the California standards, because the criteria are strict but less limiting and costly. For LL 86/2005 projects, DDC recommends that the project pursue LEED cool roof standards, and the related credit towards certification. Both strategies incorporate reflectance and emittance standards as well as SRI requirements. LEED additionally provides a standard for a combination cool/green roof. For more in-depth information regarding each standard, see the Resources section.

To help architects choose cool roofs, professionals from several organizations are setting standards and rating the roofing industry's products. These organizations list specific roofing products and provide calculators or other supportive information. Following is a list of resources (see Resources for web links)

- LEED™ certification program, which has an SRI calculator, as well as established criteria
- Cool Roof Rating Council, which administers roof testing and publishes results, by type and brand name
- Energy Star®, which has established criteria and lists compliant commercial products
- Lawrence Berkeley Lab, which lists tested results for generic and specific products
- Oakridge National Lab, which has tested reflectance / emittance over time, including SRI and calculator
- California Cool Roof Information, which hosts a Qualified Cool Roofs Products List of products that meet California's Title 24 Requirements
- ASHRAE/IES, which considers cool roof - insulation trade-offs in Standard 90.1

GOING FROM HOT TO COOL

Variety marks the roofing industry today, with more material options than ever, and environmental design adding new considerations to an architect's or facility manager's evaluation. The roofing chosen for any DDC project should be evaluated for all its performance characteristics. This manual does not recommend specific roof types, but the following is a brief description of typical roof systems, and options for making them *"cool"*.

The roof's "coolness" is really only skin deep, because reflectance and emissivity are properties of the roof's surface material. Essentially, all typical roof types can be made cool by making sure that their surfaces are white or light colored. Thus, reflectance and emittance are not factors that will restrict the architect's selection of a roofing-type. Membrane roofs, such as Ethylene Propylene Diene Monomer (EPDM) or Thermoplastic Polyolefin (TPO) are readily available in white/light colors. Other types – e.g. built-up roofing and modified bitumen – can be made more reflective with an applied coating, cap sheet or white ballast. Metal roofs can have both high reflectance and high emittance with the addition of a factory-applied "cool" paint color or a field coating.

TYPICAL ASPHALT ROOFING

Asphalt roofing is generally either built-up (BUR) or composed of modified bitumen membranes. A traditional roofing system in NY, BUR is applied in layers, alternating reinforced bituminous impregnated sheets with a viscous bituminous coating. Without a different surface layer, BUR is black, with a very low reflectance and high emittance. Reflectance tends to increases slightly over time as the black color grays. BUR systems are often surfaced, which can raise their reflectance level.

Modified bitumen membranes combine conventional installation techniques with the use of manufactured roofing sheets. The membranes are manufactured with modified rubber or asphalt-impregnated reinforced sheets. The resulting flexible product is applied and seamed with either hot asphalt, torches or cold adhesives. Modified bitumen roofing is black and has a low reflectance and high emittance.

Cool Asphalt Roofing

Asphalt roofing can be surfaced with aggregate (e.g. dark granules, white marble chips, or white coated aggregate), with a mineral surface cap sheet, or with an aluminum coating or a white reflective coating. A white coating is the most reflective of these surfaces, but all are better for reflectance than the uncoated black roofing.

There are coatings formulated for asphaltic roofing that will make them Energy Star™ compliant – see Roof Coating section in this chapter. Coatings in general tend to lengthen the life of the underlying asphaltic roofing by keeping the roof cooler and covered, slowing the loss of oils which contribute to the loss of elasticity in the material.

The cap sheet may be coated with reflective stone granules, either in the factory or in the field. “Standard” white stone granules applied at the factory will produce an initial solar reflectance of about 30 percent. “Enhanced” white granules, available from some manufacturers will produce a greater solar reflectance (varies by manufacturer). Similarly, aggregates can increase the reflectance of BUR or modified bitumen roofing. Two considerations with granules and aggregate are: most will not raise the reflectance to the .65 level required by DDC; and the rough surfaces attract dirt more readily than a smoother surface. Cap sheets are commonly used in NYC, but do not meet the requirements of DDC or Energy Star®.

REFLECTANCE AND EMITTANCE EXAMPLES

ROOFING TYPE	INITIAL SOLAR REFLECTANCE	THERMAL EMITTANCE	TEMPERATURE RISE – ROOF	SOLAR REFLECTANCE INDEX
Smooth Bitumen	0.06	0.86	83° F	-1
White Granular Surfaced Bitumen	0.26	0.92	63° F	28
Light Gravel on Bitumen	0.34	0.9	57° F	37
White-coated Gravel on Bitumen	0.65	0.9	28° F	79
Black EPDM	0.06	0.86	83° F	-1
White EPDM	0.69-0.76	0.87-0.9	25° F	84
Brand Name White Membranes	0.75-0.83	0.90-0.92	11-19° F	93-104
New Bare Galvanized Steel (Sloped roof)	0.61	0.04	55° F	46
Aluminum (Sloped roof)	0.61	0.25	48° F	56
Brand Name White-Metal (Sloped)	0.59-0.67	0.85	28-37° F	71-82
White Coatings *	0.65-0.85	0.89-0.91	9-28° F	79-107
Tinted Coatings	wide variation	0.91	wide variation	wide variation
Aluminum Coatings – Non-fibered	0.52-0.56	0.41-0.44	49-53° F	43-48
Aluminum Coatings – Fibered	0.37-0.40	0.56-0.58	62-64° F	26-30
Modified Bitumen (Source 2) **	0.26-0.32	0.85-0.91	NA	NA

Source: Lawrence Berkeley National Laboratory; Cool Roofing Material Database; LBL web site, 6/2007
Source 2: Cool Roof Rating Council; Product Listing as of 6/2007; CRRC web site
* *White coatings tested showed increased reflectance with increased thickness. Emittance remained the same.*
** *One brand showed 0.65 Reflectance and 0.79 Emittance*
🟩 *Toned roofing types are Energy Star® compliant, either for low slope/ flat roofs (0.65) or sloped roofs (0.25)*

TYPICAL SINGLE-PLY MEMBRANE ROOFING

Single-ply membranes are flexible sheets fabricated from synthetic waterproof materials. Typically, membranes are composed of a scrim, or fabric layer, for strength, and a laminated layer of flexible polymer-based material. They are often part of a manufacturer's integrated roofing system, and can be applied in a number of ways, including mechanical attachments, bonding to substrate, and ballasted. The base color of roofing membranes ranges from black to white, depending on the product's formulation. The upper surface may be pigmented coating or be ballasted with roofing granules. Its solar reflectance depends on the surface characteristics, although most membrane roofing has a relatively high emittance. There are two basic types: Thermosets, and Thermoplastics.

Thermoset membranes are made from synthetic rubber (elastomeric) polymer, and the two most popular thermoset roofing membranes are Ethylene Propylene Diene Monomer (EPDM) and Chlorosulfonated Polyethylene (CSPE). EPDM is currently the most commonly used membrane roofing system for new roofs and re-roofing in the U.S.

Thermoplastic membranes are made with plastic polymers. The two most common types are Polyvinyl Chloride (PVC) and Thermoplastic Polyolefin (TPO). Formulations and additives vary by type and manufacturer, for example, PVC membranes typically include phthalate plasticizers for flexibility, and TPO membranes sometimes require fire retardant additives.

Cool Single-Ply Membrane Roofing

Single-ply membranes are generally available with integral color in the sheet. White is available, as well as other colors, and most white sheets are EnergyStar™ rated. Additionally, EnergyStar™ compliant coatings are available for single-ply membranes that are dark colored or for retrofit applications.

TYPICAL METAL ROOFING

Aluminum and steel, often with zinc and/or tin alloy coatings, have supplanted the traditional copper for metal roofing. Uncoated metal roofing typically has a high reflectance but a low emittance. Protective coatings are often factory applied to protect the metal and improve the appearance, with the added characteristic of increased emittance.

Cool Metal Roofing

Most uncoated metal roofs, such as Galvalume™, comply with the reflectance requirements of the DDC, although the emittance is very low. A factory or field applied coating would be necessary to increase the emittance, and the final reflectance is dependent on the characteristics of the coating. Factory-applied coatings are available that use highly reflective pigments that target the infrared energy—the infrared component of sunlight is not visible, yet is absorbed by the roof as heat. These increase the reflectance of roofing, even at darker colors. There are now medium to dark colors for metal roofs that meet the Environmental Protection Agency's Energy Star® reflectance for steep-sloped roofs, which is 0.25 initial reflectance, instead of the 0.65 for the low slope/ flat roofs. Check the manufacturers for their palettes of "cool colors."

Metal roof - Jerry Uht Stadium, Erie, PA

photo: Centri; Used by permission.
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COOL ROOF COATINGS

Roof coatings can be applied to most smooth-surfaced roofs, although the formulations must be matched to the substrate. Factory applied coatings are typical in metal and some membrane roofing systems, but coatings can be field applied to both new roofs and existing roofs in good condition. Coatings extend roof life, protect the roof from UV damage and increase reflectance and/or emittance. White elastomeric and aluminum asphalt are the basic field-applied coating types.

ALUMINUM COATINGS

Aluminum coatings, which are commonly used in NYC, do not comply with DDC's reflectivity criteria. They are normally used with asphalt roofing products. In an aluminum coating, aluminum flakes in an asphalt resin rise to the surface, providing reflectance while providing UV protection. Most aluminum coatings have a reflectance over 50%, although the aluminum reduces the normally high emittance of the asphalt. Aluminum coatings may have to be recoated every five to seven years because of wear and increasing dullness, and generally have to be removed to effect repairs. Some products claim to assist in waterproofing, but shouldn't be relied upon for primary water entry protection.

WHITE ELASTOMERIC COATINGS

Reflectance in white/light coatings is achieved by pigments, such as titanium dioxide, in a carrier base, and are effectively applied in several layers over a smooth surface. They achieve an initial solar reflectance of .65 to .85. Acrylic coatings are the most common, but others include urethane, silicone, Hypalon™ and other polymer-based coatings. They can be further classified by the carrier for the coating. Solvent-based and water-based are the most prevalent, and each has specific advantages and disadvantages that should be considered with the needs and timing of the project. Solvent-based coatings can be applied over a wider range of weather conditions, including cold weather and high humidity. However, they have a high volatile organic compound (VOC) content and contain flammable components. Water-based coatings evaporate water as they cure, so the application conditions are more limited. Applications should not be planned for the winter (50 degree F typical minimum) or when rain is expected, although some the manufacturers have specialized products with better weather tolerance. Water-based coatings have low VOC content, easy clean-up, less bleed-through and often cost less. Reflective coatings are generally elastomeric and water-resistant, but should not be relied upon for primary water entry protection. The products should be washed to help maintain their reflectance, and may be re-coated after a few years to restore their brightness.

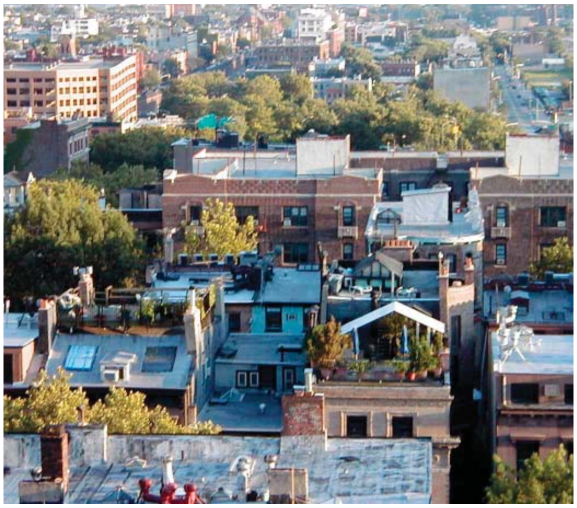


photo: Susan Drew

COOL ROOF COATING CONSIDERATIONS

The planned roofing type is the starting point for choosing a coating – compatibility is key to success. And there are hundreds of roof coatings on the market. Reviewing the project's characteristics and timing with several manufacturers will help the designer specify the appropriate coating. Considerations include the following:

- The roof membrane – The type, shape, condition (for retrofit) are all factors in coating selection. These should be reviewed with potential manufacturers to make sure that the coating type specified will adhere to the roofing and match its mechanical properties (e.g. elongation and tensile strength). Several of the large roofing manufacturers have their own coatings matched to their roofing products. Roof characteristics will determine whether a primer will be needed for the membrane or for flashing and other roof components.

- Weather and temperature requirements – Coating formulations are specific to weather expectations, including temperature, rain and humidity.
- Performance history – Product Data Sheets should have information relevant to NYC demands, matching our temperature range, rainfall and typical substrates.
- Local experience – Except for aluminum, roof coatings are not as commonly used in New York as in other parts of the country. The specifications should require a contractor who has had experience applying the selected coating type, or who undergoes appropriate training.

LEED™ APPLICABILITY (NC VERSION 2.2)

Cool roofs are eligible for credit under the Leadership in Energy and Environmental Design (LEED™) program of the U.S. Green Building Council. They are directly applicable for a possible credit under the following:

- Credit SS 7.2 Heat Island Effect: Roof

A cool roof can contribute to the attainment of several other credits:

- Credit EA 1 Optimum Energy Performance
- Credit MR 4.1-4.2 Recycled Content
- Credit MR 5.1 Regional Materials

- Cost – Costs should be compared at comparable thickness (dry film thickness).
- Specification content – The range of roofing types and coatings is very broad, and it is difficult to suggest a generic “spec.” Covered topics should include surface preparation, verification of compatibility, performance characteristics, dry film thickness, application technique, appropriate training and warrantees, and, of course, reflectivity and emissivity.

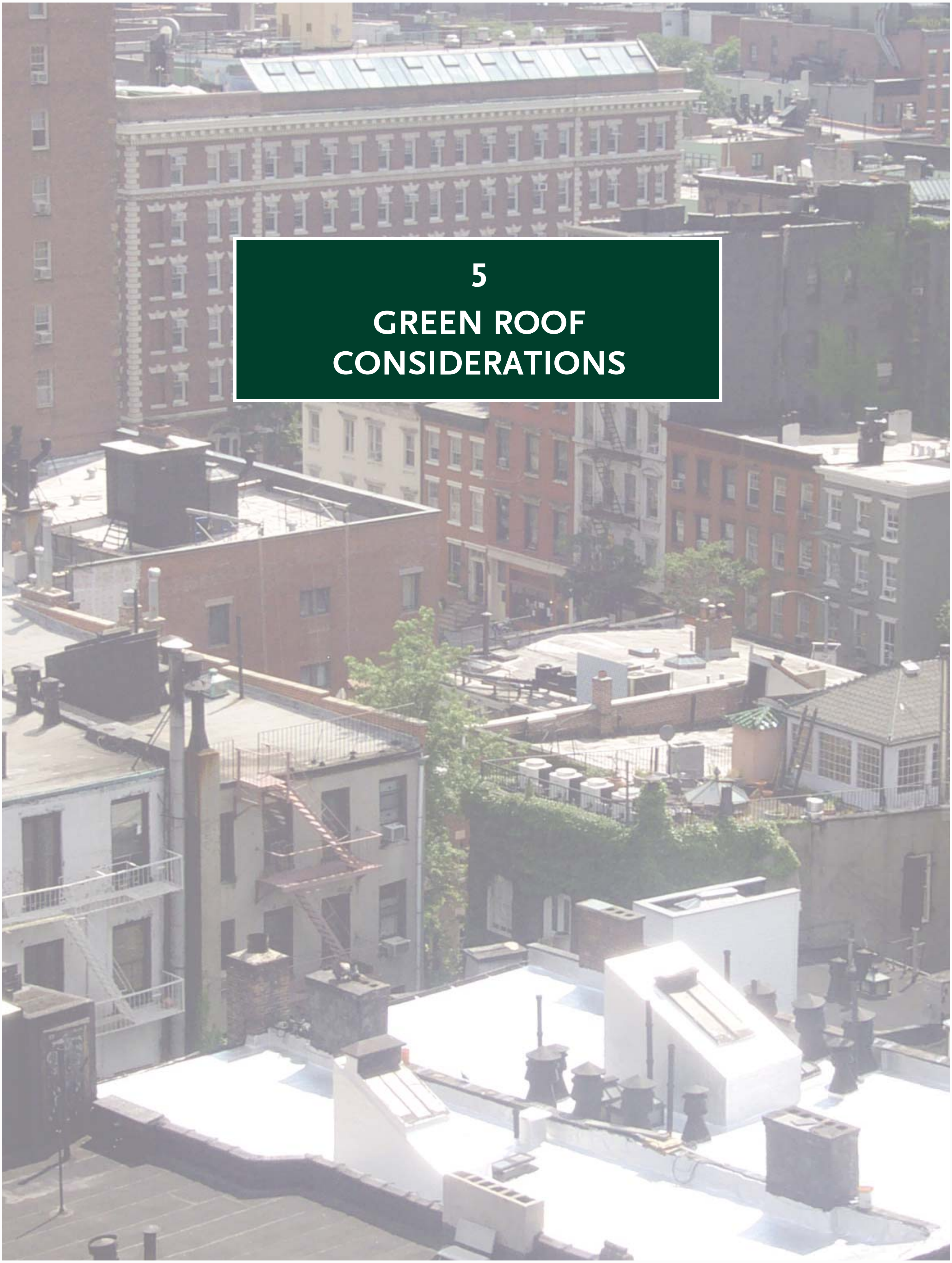
MAINTENANCE

Both recommended performance standards here – California Title 24 and LEED – are based on initial reflectance. or SRI However, as mentioned previously, the initial reflectance of cool roofs and coatings diminishes over time, as they become dirty. One recent three-year study, conducted by Oak Ridge National Laboratory, in cooperation with the Single Ply Roofing Institute (SPRI), found reductions in reflectivity ranged from approximately 30% to 50%, and leveled off after 2-3 years (emittance changed very little over time). They also found that reflectance can be significantly restored by washing the roof . Testing by Lawrence Berkeley National Laboratory found that initial reflectance could be almost completely restored by using very simple washing techniques.

If the investment in a cool roof is to be made, we recommend the concurrent development of a washing schedule, in order to preserve the initial reflectance of the cool roof. Typically, most manufacturers seem to recommend an annual washing cycle using a mild soap solution in water.

COOL ROOF RESEARCH

The National Laboratories of Lawrence Berkeley and Oak Ridge are reliable sources of past and ongoing broad-based research on both cool roofs and Urban Heat Island Effect mitigation. Both these labs work in partnership with other U.S. Agencies, such as EPA, DOE and NASA, state governments and roofing industry partners. Information and trends can be found on their web sites – see Resources section.



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GREEN ROOF CONSIDERATIONS

GREEN ROOF CONSIDERATIONS

Despite their exotic sound, green roofs have been around in various forms for centuries. For thousands of years, from the Hanging Gardens of Babylon to the roof gardens of Le Corbusier, the habitable garden and the flat roof worked together to provide green open space. Why they became conceptually separated is uncertain: devoid of plants and inhabitants, the flat roof became a mainstay of modern design, while the roof garden was virtually forgotten. With the growth of the environmental movement, green roofs have been resurrected. However, in America they have been promoted largely as an environmental asset, often without emphasizing their value as amenities in crowded urban settings. To date, there is not a substantial body of scientific evidence supporting the claims made for green roofs, and this has made them a hard sell in the public sector

Green roofs are fairly expensive, and may be justified for DDC projects in cases where they perform both recreational and environmental functions. In contrast to the American experience, in German cities, where urban green space is at a premium due to the urban growth boundaries that limit sprawl, developers are often required to provide green roofs to compensate for lost open space. Consequently, roughly 14% of the roofs in Germany are greened–an enormous percentage compared to the United States. Most American or Canadian manufacturers today use components and growing media systems developed in Germany.

GREEN ROOFS AND DDC'S SUSTAINABILITY BUDGET


The Hallmark, Battery Park City, NY

photo: Mathews Nielsen Landscape Architects P.C.

DDC has determined that green roofs can command a considerable portion of the construction budget available for sustainable design strategies, without paying it back in operating energy cost savings. Because of their cost, extensive environmental green roofs should be considered very cautiously for projects where the budget for green building strategies is limited, e.g. to 2% or 3% of the project cost. Consider DDC's typical two-story building from the energy model chapter, at an assumed construction cost of $350 per square foot. Installing an extensive green roof over the entire roof would increase the construction budget from 1-2%. The green roof could therefore consume most of the money allocated for green features, leaving little for other proven, more effective, green building strategies. (High-rise building would obviously apportion the additional cost over many floors.) In this way, it could have a negative impact on the important environmental challenges, such as reducing energy consumption and improving water quality, which New York City needs to address by the most effective means available.

So, as a general policy, DDC does not encourage the use of green roofs as a sustainability strategy on City projects, and recommends more cost-effective, environmentally-beneficial strategies such as street trees, light-colored surfaces, and permeable paving–and building-related energy improvements. However, it is important to note that green roofs have numerous other benefits, primarily those in human terms. A green roof might be the right solution in a particular situation, and would be supported by DDC. Examples are:

- As a public or staff amenity. Intensive green roofs can provide protected, usable outdoor space for libraries, residential facilities and 24-hour agencies, such as Police and Fire. An extensive green roof might provide a welcome visual amenity for cultural institutions or a situation with a bleak view.

- As a mission-related or educational tool. An example is the new building at the Queens Botanical Garden, where the green roof supports the Garden's mission and is usable by visitors.

Although green roofs offer many benefits, they are not the environmental panacea sometimes put forth. Design teams should review the project-specific goals, alternate methods of providing green open space and controlling stormwater and craft an effective environmental approach.

GREEN ROOFS IN ENVIRONMENTAL TERMS

STORMWATER MANAGEMENT


photo: 2004 Roofscapes Inc., Used by permission; All rights reserved

Roof edge, showing drainage elements

Green roofs are one strategy for controlling runoff. Rainfall entering a green roof is stored in the substrate (soil medium), is absorbed by plants' root systems, and retained in plant foliage. Water is released through evapo-transpiration, slow percolation through soil and recycled back into soil through capillary action. Additional water storage capacity is provided by some green roof systems in a drainage layer that can hold up to 1.5 inches of water depth under the entire green roof system. Because of their ability to absorb and retain water, green roofs have been put forward as a strategy for reducing runoff–potentially a great benefit to New York City's waterways, which are often polluted when storms overwhelm the combined storm sewage system (known as a "Combined Sewer Overflow," or "CSO" event).

Because of New York's combined sewage system, new construction projects in the Boroughs (except Manhattan) are required by the Department of Environmental Protection (DEP) to detain stormwater on site with a tank or other means. The detention amount is site-specific and depends on several factors, including pre-development condition, site area and permeability. A green roof could potentially be part of an overall site stormwater detention strategy. This could be particularly useful on a site with unfavorable geology or groundwater hydrology, significant sol contamination or other prohibitive condition. However, DEP has not yet accepted a green roof in lieu of detention systems.

Physical research into the stormwater effectiveness of green roofs in the Northeast is starting. To date, the jury is still out on whether they are as effective as other (typically less costly) stormwater management strategies, such as "blue" roofs, or roofs that have a collared drain, cisterns, on-site retention and detention techniques, such as tanks and drywells, permeable paving, and reduction of paved surfaces in the streetscape. A small-scale study in Seattle measured the effectiveness of green roofs to manage stormwater, over an 18 month period. On four sites with various green-roof thicknesses and planting medium, they found significant runoff volume reduction (65% +) and peak flow reduction. One of the key questions was whether a green roof could replace a detention tank, and the answer was "it depends." (See http://www.seattle.gov/dpd/GreenBuilding/OurProgram/Resources/TechnicalBriefs/DPDS_009485.asp#monitoring for a link to the study.)

In 2006 The Natural Resources Defense Council studied nine cities in North America with combined stormwater and sanitary sewer systems; each city is using green infrastructure as part of its strategy for controlling runoff and avoiding CSOs. Green roofs are part of each city's approach, combined with rain gardens/vegetated landscape, permeable paving, rainwater collection and other infrastructures such as constructed wetlands. Several, notably Chicago, Toronto and Portland, are monitoring the ability of green roofs to absorb and slow down the runoff from storms. The early results are encouraging, but samples are small and it is not clear that the research measured effects of intense storms, which are the ones that cause CSOs. The US Environmental Protection Agency, in its Green Roof Research Project, is partnering on several projects to test green roof technologies. One of these is in partnership with Penn State University, studying stormwater volume discharge and pollutant runoff. A final report from EPA is expected soon.

As green roof research becomes more definitive, and technology more evolved, NYC may incorporate green roofs in its stormwater management policy. At the time of writing, green roofs seem unlikely to solve the City's CSO problem to any great extent.

ENERGY CONSERVATION

Green roofs, like reflective roofs, moderate the transfer of heat and cold into a building, potentially reducing the cooling loads and conserving energy. The amount of energy saved is dependent on several factors. Among them are: the amount of roof insulation used; the height of the building; the climate and microclimate of the building; and the type and coverage of the green roof. The energy study in this report showed that in NYC's climate, and with energy-code compliant buildings, green roofs provide negligible energy savings in individual buildings.

As a city-wide strategy, green planted roofs (like cool roofs) can help mitigate the heat island effect. They replace the normally dark roof surface with plants, which shade the roof surface and absorb rather than release the solar radiation into the surrounding atmosphere. In addition, plants help keep the air cool through evapotranspiration by releasing moisture into the atmosphere. If conventional dark roofs can attain temperatures as high as 190° in New York City; a green roof under the same weather condition will not exceed 77°.[1]

AIR QUALITY IMPROVEMENT

Both green and reflective roofs improve air quality by controlling heat gain, and the associated greenhouse gas emissions and the generation of atmospheric ozone (smog). And vegetation, whether a planted roof, trees or other site plantings, reduce airborne particulates; dust particles are trapped on foliage and also within the soil matrix.

BENEFITS IN HUMAN TERMS

There is no disputing the fact that people love gardens, and by extension, green roofs, because they are attractive, relaxing, and peaceful. They are particularly loved in the city as providers of valuable open space. Though the environmental discussion of green roofs continues, a truly compelling argument for them can be made in terms of the benefits conferred directly to people.

OPEN SPACE

Intensive or semi-intensive green roofs offer additional recreation and leisure space. This is particularly valuable in dense cities like New York, where open space is at a premium. The provision of protected, inhabitable green roofs, also called roof gardens, are extremely valuable amenities that could benefit many city buildings. Roof- scapes designed for aesthetic and recreational purposes (a.k.a. intensive green roofs) are quite different from extensive roofs designed solely for environmental mitigation. They include a diversity of plants, including tress and shrubs, and accessible/paved areas for the users. The cost of occupiable roofs are


photo: Mathews Nielsen Landscape Architects P.C.

Armory, Manhattan

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[1] *White, John W., "Exploring Tomorrow's Technology in Roofing"*

several times that of extensive roofs, because they must provide for public safety and egress, greater soil depth, enhanced structure, and more diverse plantings that may require irrigation systems and more extensive maintenance.

For DDC projects, roof gardens installed for recreational or aesthetic reasons would be limited in size and application, in order to be affordable, and be considerably smaller than an extensive green roofs installed for environmental reasons. Green open space at ground level should be sought first – plentiful and healthy trees, courtyards and gardens, with sustainable planting and landscape maintenance practices.

BIOPHILIA

Biophilia, or literally, "love of nature," makes the most compelling case for green roofs to date. Used as a term referring to the connections humans seek to the natural world, biophilic design has been seen to promote physical and emotional well-being, stress reduction, learning and healing, among other positive attributes. Biophilic building elements, which also include daylighting and green walls, have been demonstrated to promote physical and emotional well-being, stress reduction, worker productivity, learning, and healing, among other benefits. In cases where human wellness is a particular project design goal, this may achieved by incorporating green roofs. It can also be inferred that biophilic building design has educational properties, in that it promotes an awareness of and appreciation for the natural world.

DDC already has one project for which a green roof has been incorporated for its biophilic properties: The NYC Department of Homeless Services Emergency Assistance Unit in the Bronx, currently in design. An extensive green roof will be visible from the facility's main waiting room to assist in reducing stress and promoting a calmer atmosphere for both those served by the agency and the staff.

Given that it has been proven that views of planted landscapes have a positive effect on people, in terms of well-being, increased productivity and improved health, DDC will be encouraging project teams to explore all ways of providing planted areas, for the public and for city employees, consistent with the project goals and budget.

GREEN ROOF DURABILITY

Green roofs protect the membrane in several ways - by reducing the expansion and contraction due to thermal cycling, by shielding the roof from the degrading effects of U.V. and by protecting the roof from mechanical damage. Green roofs stabilize temperature of the roof membrane, thereby reducing cracking and subsequent leaks resulting from expansion and contraction. In a NYC summer, an un-protected roof exhibits temperature fluctuations of up to 90°, whereas a covered green roof dramatically dampens the daily membrane temperature fluctuations (e.g. 9° in July of the energy model case study).

How much this extends the life expectancy of the roof remains an open issue; much of the data reflects experience in Germany. Research done in the Northeast is in its infancy, because planted green roofs are relatively new. Some increased longevity is reasonable, because a green roof system protects the roof. Expectations, however, that green roofs will double or triple the life expectancy of roof membranes, may be over-optimistic, since standard design practice pulls the green roof away from the most fragile areas near penetrations, parapets, and flashing, where leaks are most likely to occur. Also, the warrantees given by green roofing manufacturers match, but do not exceed, those of standard roofing membranes. Still, there are particularly destructive environments where the protection offered by green roofs could prove beneficial, potentially saving the city substantially in roofing costs and leak repairs caused by premature membrane failure.

Extending the life of the roof membrane may result in cost savings. How much depends on the increase in longevity. If green roofs really last twice as long, then over time they are no more expensive than standard roofs, which cost about half as much (although the extra money must be put up first.) Longevity engenders further regional benefits that are derived from reducing resource use and sending less material to landfills.

OTHER BENEFITS

Although typically not key to decisionmaking, there are other benefits. Plants absorb sound in the urban environment; on a green roof, sound absorption also occurs in the soil and the trapped layer of air between the substrate and roof membrane. Green roofs increase habitat for species such as birds and butterflies, and increase biodiversity with diverse plant material.

TABLE 4: GREEN ROOF EXAMPLES IN NYC

RECENT PROJECTS IN NYC	
Calvary Hospital, Bronx (2002)	Intensive
Solaire Residential Building, Manhattan (2003)	Intensive (5,000 SF) Extensive (4,800 SF)
Silvercup Studios, Queens (2003)	Extensive (35,000 SF)
Nassau Brewery Ice House Renovation, Brooklyn (2003)	Extensive & Intensive
Reingold Gardens Senior Housing, Brooklyn (2004)	Extensive (3,000 SF)
Chelsea Residence Supportive Housing, Manhattan (2004)	Intensive (5,000 SF)
Calhoun School, Manhattan (2005)	Intensive (2,500 SF)
St. George Ferry Terminal, Staten Island (2005)	Semi-Intensive (18,000 SF)
Simon Stock School, Bronx (2005)	Extensive (3,500 SF)
Tribeca Green, Manhattan (2005)	Extensive (11,300 SF)
Bronx County Courthouse, Bronx (2006)	Extensive (10,000 SF)
Gratz Industries, Queens (2007)	Extensive (8,500 SF)
Queens Botanical Garden, Queens (DDC Project) (2007)	Extensive (8,000 SF)
PROJECTS IN PROGRESS IN NYC	
Kingsbridge Branch Library, Bronx (DDC Project)	Extensive (4,500 SF)
Brooklyn Botanic Garden Visitor Center, Brooklyn	Extensive (8,000 SF)
Mosholu Golf Course Clubhouse, Bronx	Extensive (9,000 SF)

GREEN ROOF TECHNICAL CONSIDERATIONS

Long-term success with green roofs is dependent on proper system design and installation. Recent technological advances in roofing components have resulted in reliable products with warrantees comparable to conventional roofing assemblies. The challenge lies in determining the right balance among the considerations – structure and soil depth; use and accessibility; vegetation assemblies (soil medium and plant material); modular units or mat system. Continuing education of designers, administrators, contractors and manufacturers to better understand the benefits and limitations of green roofs is essential.

Extensive green roofs are suited to locations where they can be viewed from above and enjoyed by neighbors, especially when combined with accessible, intensive or semi-intensive green roofs. Appropriate DDC buildings types include gymnasiums, garages, maintenance buildings and detention facilities.

Intensive or semi-intensive green roofs offer convenient, safe pedestrian access, and are cost-effective when compared with additional land acquisition costs. DDC facilities that could benefit from accessible roof space include day care centers, senior centers, libraries, museums and municipal office buildings.

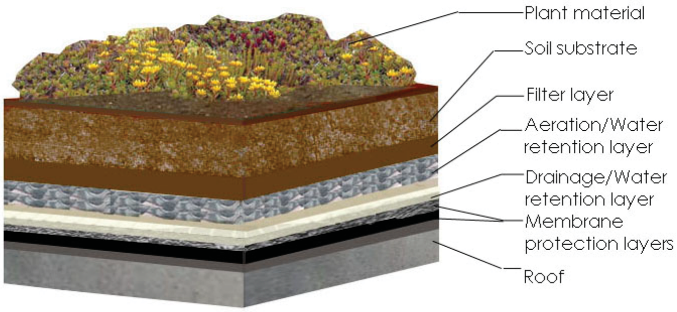
TYPICAL GREEN ROOF TYPES

Green roofs may be retrofitted on an existing roof or installed over a variety of new roof systems. They may be installed over a single-ply roof system on a concrete or steel deck for the most cost-effective, efficient construction. If they are installed over an multi-layer asphalt-based system, the roof must be covered with a root barrier. Insulation, as required by building design, is installed under the waterproof membrane and may be tapered to achieve positive pitch to drains. Alternatively, the underlying roof slab may be sloped as appropriate to the architectural intent.

Green roofs are classified as extensive, intensive, or semi-intensive. Systems vary by manufacturer but the basic components are as follows for each green roof type:

EXTENSIVE GREEN ROOFS

Extensive green roofs consist of low vegetation planted uniformly over the roof. They are the least expensive type of green roof, and are designed primarily to provide environmental and/or visual benefits. They are lightweight, low maintenance and usually inaccessible to the public. Extensive roofs are designed for maximum thermal and hydrological performance and minimum weight load, while being aesthetically pleasing. The plant material is typically comprised of drought-resistant low-growing species that are capable of withstanding hot, dry and windy conditions and have the capacity to store water within their foliage. As a result these types of roofs do not require mechanical irrigation systems and need only minimal maintenance. The growing medium is a mineral-based mixture, ranging in depth from 2 inches to 6 inches, with a fully saturated weight load of 7.5 to 14 pounds per inch soil depth per square foot, resulting in 16 to 35 pounds per square foot. Extensive roofs can be installed on roofs with slopes up to 40%. Maintenance of an extensive roof is limited to watering in the first year during the plant establishment period and occasional weeding of invasive species for 3-4 years following installation. Extensive roofs are not intended as recreational space, although they can provide a pleasing view.



courtesy: Mathews Nielsen Landscape Architects PC

Extensive Greeen Roof - Typical Section

Basic components of extensive green roofs are as follows:

- **Membrane protection**: Most manufacturers require a root resistant membrane that passes the German FLL Standard to provide a warranty on their system. Some new membranes developed specifically for green roof applications, although still bituminous, contain a root-deterring chemical or metal foil between the membrane layers and the joint/seam lines to prevent root damage.
- **Drainage/Water retention layer**: Moisture retention mat that stores water for plant roots to take up in low rainfall periods comprised of fiber matting (often recycled polypropylene).
- **Aeration/Water retention layer**: Free-draining molded polyethylene (recycled) three-dimensional panel that stores water in pockets and provided domes for air circulation to roots.
- **Filter layer**: Used to separate soil substrate from clogging the drainage layer fabricated from non-woven polyester fibers.
- **Soil substrate**: Lightweight, engineered growing medium composed of appropriate mineral aggregates (expanded clay, shale, slate, volcanic rock, pumice, zeolite or vitrified diatomaceous earth)

and organic materials (sphagnum moss peat, coir, composted barks or municipal yard waste, or pasteurized manure). The proportions and components will vary based on the weight, water-holding requirements, plant selection and soil depth. In general 80–85% is composed of mineral aggregates and 15-20% is organic. Soil depth ranges from 2 inches to 6 inches.

- **Irrigation**: Not required or recommended. Hand watering will be necessary during the first year of plant establishment.
- **Plant material**: Plant characteristics must include shallow root systems, resistance to drought, frost, wind, and intense solar exposure, and the ability to regenerate. Additionally, they must be appropriate to the climatic zone and specific microclimate of the site. Plant types include sedums, herbs, creeping perennials, alpines, and some wild flowers and grasses. Plants may be installed as cuttings, plugs or in pre-grown mats (trays or pallets). Cuttings or seeds are the least expensive but take the longest to become established; pre-grown mats are the most expensive but produce an instant green roof.
- **Fire breaks/barriers**: Recommended every 130 feet on large roofs, as well as around all rooftop openings and at the base of walls that contain openings over flashed areas at perimeter, drains, etc. These may take the form of vegetation-free zones such as concrete or gravel maintenance paths.

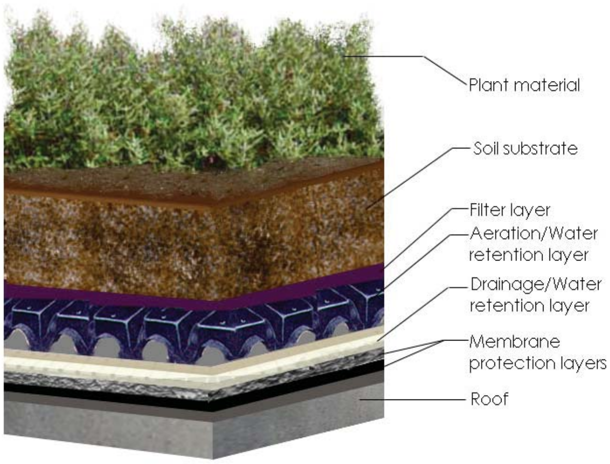
Extensive green roofs can be implemented using modular “containers” or a continuous mat system.

INTENSIVE GREEN ROOFS

Intensive green roofs are essentially roof gardens intended for human use which consist of a diversity of plants, including shrubs and trees. These roofs generally require traditional landscape maintenance, infrastructure such as a water collection system, irrigation and fertilization, and provision for access and egress. Because of the plant types, the growing medium needs a soil depth greater than 12 inches. It is heavy because of its depth and composition; the saturated weight load of an intensive roof ranges from 60 to 200 pounds per square foot. Intensive roofs are appropriate for flat roofs with a slope up to approximately 3%, because beyond that the slope cannot be compensated for with pavers. Costs for this type of green roof range widely depending on the actual soil depth, container types and amenities for public access, but expect to pay several times the cost of extensive roofs.

Basic components of intensive and semi-intensive green roofs are as follows:

- **Membrane protection**: A more substantial root barrier than is used for extensive roof systems due to the more aggressive nature of the root of larger plants. Often embedded directly into the roofing membrane and reinforced with polyester and coated with ceramic granules.



courtesy: Mathews Nielsen Landscape Architects P.C.

Intensive Greeen Roof - Typical Section

- **Drainage/water retention layer:**

  Same as for extensive roofs.
- **Aeration/water retention layer**: May be the same as for extensive roofs, or stronger depending on soil load.
- **Filter layer**:

  Same as for extensive roofs.
- **Soil substrate**:

  55% mineral based soil and 45% organic soil (compositions of both as described in extensive roof.

soils). Soil depths range from 6 inches to 12 inches for semi-intense to 12 inches and greater for intensive green roofs.

- **Irrigation**: An automatic system is optional but is recommended, to reduce labor costs for hand watering on a regular basis. Some systems are manufactured with self-sustaining passive irrigation called a ponding element; other systems have solar powered automatic irrigation controls that feed off a cistern. Drip irrigation systems are preferred because they put the water directly at the plant roots and minimize water loss due to wind and evaporation.
- **Plant material**: Choice of plants will vary depending on soil depth, solar and wind exposure but may include trees, shrubs, perennials, vines, ground covers and grasses. Plants may be installed as for extensive roofs but will also include containerized and even balled and burlapped material.
- **Fire breaks/barriers**: Not required due to the use of irrigation and deeper substrate soils.

Semi-intensive green roofs are hybrids, with a greater diversity of plants than the extensive roof, but not the soil depth to support trees or larger shrubs. Plant material may include perennials and small shrubs in addition to low-growing ground covers. The selection of species determines the need for irrigation and the extent of maintenance. The growing medium, at 6 inches to 12 inches, is a combination of mineral-based and traditional organic topsoil resulting in a saturated weight load of 35 to 60 pounds per square foot. These roofs can potentially provide more visual variety than extensive roofs, at an intermediate cost, as was done at the Gap Headquarters.

DESIGN CONSIDERATIONS

WHICH ROOF?

Green roofs can be installed on flat or sloped roofs. Slopes up to 45° (1:1) can receive extensive green roof systems. Roof slopes in excess of 14° (3:12) require landscape retainers, or a raised grid structure to prevent erosion. Intensive roof systems need to be installed an relatively level roofs to avoid expensive custom leveling devices under planters and pavers.

Green roofs can be installed as a retrofit or on new construction. All green roof manufacturers will install on an existing building, provided that the old roof is entirely removed to the structural deck and that the load bearing capacity is consistent with the new system. Warranties for retrofit systems range from 10 to 20 years, comparable to those offered to green roofs in new construction.

Life Expression Wellness Center, Sugar Loaf, PA.

photo: 2004 Roofscapes Inc., Used by permission; All rights reserved

Some manufacturers provide modular soil and plant grids that can be installed over an existing roof membrane. Prerequisites to this type of installation include an inspection and evaluation of the existing roof and structure by a structural engineer, and evaluation by the original roofing contractor (if the roof is still under warrantee) to determine weight load and soil depth of the grids. (Typically, a warranty will not be offered for a continuous system installed over an existing roof.)

EXTENSIVE, INTENSIVE OR SEMI-INTENSIVE?

Any type of green roof can be effective for cooling the roof and helping to mitigate the urban heat island effect. The nature of the green roof is part of the project's design concept. The design team should consider several factors, including the following:

Cost and priorities. A green roof is one of many green building strategies that a project can implement to help with heat island mitigation. Because a green roof is more expensive than a typical roof, at least in first cost, it is important that one not be implemented at the expense of other very effective measures to reduce global warming, such as daylighting, lighting controls and more efficient mechanical systems.

Usable outdoor space. Outdoor space is an amenity, and often a luxury, in New York City. An intensive green roof offers the potential for creating occupiable outdoor space that could be particularly useful to DDC agencies. City building types that would benefit from protected, outdoor space include:

- Libraries– Community space and protected reading space
- Cultural institutions– Event or exhibit space
- Residential facilities– Protected outdoor space for shelters, daycare facilities etc.
- 24-hour facilities– Outdoor relaxation space for intense operations such as police and fire

photo: Mathews Nielsen Landscape Architects P.C.

The Hallmark, Battery Park City, New York

Cooling benefits. For certain building types, extensive green roofs would potentially keep them cooler in the summer. Although the energy model demonstrated very modest energy savings for the "typical" air-conditioned DDC building used, DDC builds and renovates many facilities that fall outside that definition. There are large one-story buildings, such as maintenance facilities, that are not air-conditioned and an extensive green roof may keep them cooler, and encourage the use of natural ventilation.

Structural capacity. An extensive green roof can be installed with little or no structural reinforcement of the building, but an intensive roof requires more structural consideration.

Accessibility. Intensive green roofs are meant for people to use, and therefore have requirements for accessibility. They must provide access in accordance with the Americans with Disabilities Act and NYC laws. The allowable occupancy will be determined by the exit capacity on the roof. Some usable roof area could be limited by the stair capacity, and the design may have to create one area for people to use, and prevent occupancy of the remainder. This would be an opportunity to combine intensive with extensive roof systems, allowing the users to visually enjoy the (inaccessible) extensive area.

Reflectivity of pavers. Intensive green roofs usually contain paved, accessible areas. The design team should remember to specify a high albedo (cool) paver.

Maintenance. The choice of roof type - extensive, semi-intensive or intensive - must be matched with the client agency's ability and commitment to provide the appropriate maintenance.

MODULAR OR CONTINUOUS EXTENSIVE ROOF?

Extensive green roof systems can be installed in two ways: modular systems, in which self-contained containers/trays are individually placed on the roof and linked together for coverage; and continuous systems, in which the components are installed layer by layer across the rooftop.

Modular extensive systems

Modular systems utilize containers or trays or palettes, specific to the manufacturer. Modules come in

Installation of modular system

photo: GreenGrid™; Used by permission

a variety of sizes, generally no larger than 4 feet square, and in depths ranging from 2 to 8 inches. Each module contains layers similar to a continuous roof, and the modules are elevated above the roofing to allow for drainage and air circulation. Rainfall that exceeds the storage capacity of the soil volume is slowly released through small drainage holes at the top of each waffled compartment. Soil and plant selections are similar to those described below for continuous green roofs. Trays may be planted on site or pre-grown at an off-site nursery. Drip irrigation may be installed, depending on soil depth and plant species. (An alternative to the trays are systems that provide growing medium in flexible modules, or sacks, that are placed on the roof over a geotextile or drainage product.)

Modular systems may be installed over a new or existing roof. Prior to installing the system over an existing roof, a structural engineer must evaluate the capacity of the roof structure to sustain the load of a green roof. In addition, a roofing contractor must evaluate the remaining useful life of the membrane, and if it is still under an original warrantee, whether the system will accept the modular system without jeopardizing the remaining warrantee. If the existing roof has a bituminous membrane, then a roof barrier underlayment is required prior to laying the trays.

Advantages. Manufacturers of these palettized systems cite the following: 1) rapid installation; 2) no seasonal installation limitations if pre-grown; 3) no additional curbing or edging required; 4) superior drainage and airflow capacity; and 5) ease of leak repair and reinstallation of vegetation. The leak detection method is the same as that for continuous green roof systems.

Disadvantages. Disadvantages include the following: 1) visibility of module edges until plants become established; 2) cumbersome installation of pre-planted modules (weight range 200-250 lbs each at 2" soil depth, some trays); 3) lack of single source warrantee on roofing and planted components; 4) less moisture available for plant roots due to rapid draining and airflow, possibly UV degradation of exposed plastic; and 5) may be no cost savings in comparison to the continuous green roof systems.

photos: The Garland Company, Inc; Used by permission

Continuous extensive systems

Continuous systems are comprised of a sandwich of layers, which are installed across the rooftop. Typical component layers are those described earlier under Typical Green Roof Types. A plan for the entire roof is developed, locating vegetation-free zones as needed along the perimeter and around rooftop openings, flashed areas at drains etc.

Advantages: Advantages include the following: 1) easier to design and install on sloped roofs (over 5% slope) than a modular system; 2) visually seamless; 3) single source warrantee available on entire system; and 4) good water retention capacity for plant roots.

Disadvantages: Disadvantages include the following: 1) leak repair requires more invasive procedure to soil/plant section and likely requires installation of new plants within repaired area; 2) plants must be installed during proper seasons, which may conflict with project schedule; 3) edging required between soil medium and gravel stops at drains, parapets and penetrations; and 4) may be no cost savings in comparison with modular green roof systems.

IMPLEMENTATION CONSIDERATIONS

PERFORMANCE STANDARDS

The U.S. green roofing industry uses standards for the components, although there is not yet a comprehensive green roof standard.

- All American manufacturers of roofing components for green roofs use recognized industry standards based on either American Society of Testing and Materials (ASTM) Canadian General Standards Board (CGSB), or International Organization for Standardization (ISO).
- ASTM has established a Roof Task Force E06.71 that is in the process of developing guidelines and procedures for testing green roof products.
- Other components of green roofs such as drainage layer, filter fabrics or water retention mat are products certified for use in green roof applications by Forchungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL), the German governing body that issues guidelines for green roof practices. ASTM standards are pending for these products.
- The National Roofing Contractors' Association has developed guidelines for waterproofing when used in conjunction with green roof installations.
- Soil components are tested according to ASTM sieve analysis and standard chemical and biological criteria, as would be typical for any manufactured soil.
- Plant material is specified according to ANSI Z60, as would be typical for all plant material.

SPECIFYING GREEN ROOFS

Writing a complete performance specification for an extensive green roof is not practical at this time. The green roof manufacturing industry in the U.S. and Canada is not standardized in its product offerings, bundled components or warrantee applications. Each of the major manufacturers has developed proprietary non-interchangeable products that must be used as a package in order to obtain its warrantee. Some companies will supply and warranty an entire system, including the membrane, soil and plants. Others will supply the trays with soil and plants, or other combinations. DDC must publically bid its projects, and the project team should discuss the appropriate specifications with DDC - several extensive roofs have been installed on DDC projects in recent years.

Specifying an intensive roof is easier than specifying an extensive roof because it is made up of different components for which there are many precedent specifications (pavers, pedestal pavers, planters/containers, planter drainage and insulation, lightweight soil, plant material).

PLANTS FOR EXTENSIVE SYSTEMS

The plants can be "planted" on the roof in a number of ways. They can be grown from seed; introduced

LEED™ APPLICABILITY (NC VERSION 2.2)

Green planted roofs are eligible for credits under the Leadership in Energy and Environmental Design (LEED™) program of the U.S. Green Building Council. They are directly applicable for the following:

- Credit SS 6.1 and 6.2 Storm Water Management
- Credit SS 7.2 Heat Islands Effect: Roof

Additionally, a green roof can contribute to the attainment of other credits:

- Credit SS 5.1 adn 5.2 Site Development
- Credit WE 1.1 and 1.2 Water Efficient Landscaping
- Credit EAI Optimum Energy Performance

as plugs; delivered as an established mat or module. Each has its advantages and disadvantages, as summarized in the plant propagule chart below.

PLANT PROPAGULE	ADVANTAGE	DISADVANTAGE
Hydroseeding	Rapid installation, very low cost	Large roofs only; higher initial maintenance
Seeding (hand)	Fast installation; low cost	Limited species; higher initial maintenance
Cuttings/Sprigs	Lower material cost than plugs; good diversity of species	Twice as long to cover area as plugs; same labor cost as plugs; will require watering during establishment
Plugs	Highest survival rate of lower cost methods; rapid spread/growth rate; good diversity of species	Moderate cost due to labor; will require watering during establishment period
Container/Pot	Only necessary for large plants and soil depths in excess of 8”	High material cost; labor intensive
Mats/Rolls	Very rapid installation; no seasonal limitation; instant full coverage	Moderate to high cost (varies with species)

There is a wide variety of plant material that is suitable for green roofs. The most suitable species for shallow soils in New York City are from the genus Sedum because they have the following characteristics:

- Foliage absorbs water which is slowly released to roots in dry spells
- Fleshy foliage and stems absorb water thus precluding spread of fire
- Rapid self-propagation when foliage is in contact with soil medium
- Capable of withstanding extreme climatic conditions: minimum temperature - 15°; maximum temperature 130°; up to 30 days without rain once established
- Rarely attacked by pests or diseases. Any problems usually arise from lack of sunlight or prolonged soil saturation
- Roots are fibrous and non-aggressive and will not attack roof membrane
- Plants remain low-growing, require no pruning, dead heading or mowing.
- Wide diversity of textures and colors that include evergreen, semi-evergreen, flowering and deciduous species. Over 30 species and hundreds of cultivars are native to North America

Other suitable plants for extensive and semi-intensive green roofs include those that are generically known as low-growing grasses, alpine plants, herbs and wildflowers. Intensive roofs are designed for a variety of plants, chosen for their aesthetic and functional characteristics as appropriate to the roof’s human function, although they must be able to withstand the wind and microclimatic conditions of rooftop New York, which are fairly severe.

IRRIGATION

Extensive Green Roofs. During the first growing season, or establishment period, all plants (except pre-grown, well-established trays) will require supplemental water either by hand or by using a built-in drip irrigation system. Extensive green roofs planted primarily with drought tolerant plants will only require watering in times of extreme drought (no rainfall for 20 days with temperatures exceeding 80° F). Green roofs that use less drought tolerant plants, regardless of soil depths, should have automatic drip irrigation systems.

Semi-Intensive. Drip irrigation will be required as people opt for a semi-intensive roof to gain additional soil depth for greater diversity of plants.

Intensive Green Roofs. Plants used on intensive green roofs are not as drought tolerant as species typically used on extensive roofs, therefore supplemental water in the form of drip irrigation is required for the life of the roof.

MAINTENANCE CONSIDERATIONS

ROOF MAINTENANCE— WHAT ABOUT FINDING A LEAK?

Maintenance and routine monitoring of a green roof underlayment is no different than maintenance of any comparable roofing system. The key issue is access to potential roof leaks under a continuous green roof system. Because roof leaks typically occur at edges (bulkhead, parapet or vertical walls) or penetrations (vent, pipes, drains), manufacturers recommend leaving a space (12" width) around those locations for ease of repair. In the unlikely event that a leak is detected under the green roof system, a procedure exists for cutting out and removing a section of green roof and reinstalling it after repair.

Green roof installation of mats

photo: Siplast; Used by permission

There is no data to suggest that a green roof is more likely to leak than any comparable roof system. In fact, the membrane is much more protected from thermal stress, U.V., and physical damage. One strategy is to use a fully adhered waterproof membrane such as a fluid applied, seamless, rubberized asphalt that is placed directly on the roof deck. Any leak that develops with such a system will express itself inside the building at the point where the leak occurs. Water cannot travel under the membrane and flow to another point as it would with sheet applied membranes or other non fully-adhered systems.

An inexpensive method for locating damaged waterproofing underneath vegetated covers is the electric field vector mapping (EFVM) procedure. This method works by charging the moist media layer of the green roof with electricity and then looking for electrical grounds caused by moisture in contact with an underlying steel or concrete deck structure. The EFVM method can locate pin-hole size defects as readily as large flaws. In most cases the system need not be installed with the green roof system to eliminate the initial capital cost. The only requirement is that the green roof be designed to be compatible with EFVM; waterproof membrane must exhibit electrical resistance. This method is useful in both retrofit and new construction as well as on sloped roofs where flood testing cannot be done.

PLANT MAINTENANCE—EXTENSIVE ROOFS

The planting on a green roof, regardless of specific factors cited below, will require routine maintenance. The first 2-3 years require most frequent attention until such time as the plants provide complete coverage and develop full root systems. Facility managers should consider engaging a landscape maintenance company on annual contract to provide routine or specialized maintenance.


The Armory, Manhattan, New York

photo: Mathews Nielsen, Landscape Architects P.C.

Year 1

These tasks may be included in a twelve-month plant guarantee if specified in the original construction documents.

- Weeding every month between May and September
- Watering every week for the first six months unless there has been adequate rainfall (1" in a week)
- Slow release fertilizer application, once or twice in a year
- Check/clean roof drains 2-3 times per year

Year 2-3

A portion of these tasks can be minimized or eliminated for the Agency if the facility enters into a landscape maintenance agreement with the original landscape installer.

- Weeding 2-3 times during the growing season, depending on speed of coverage
- Watering every 2-3 weeks unless there has been adequate rainfall (1" in a week)
- Slow release fertilizer, once or twice a year
- Check/clean roof drains 2-3 times per year

Year 4 and onward

A portion of these tasks can be minimized or eliminated for the Agency if the facility enters into a landscape maintenance agreement with the original landscape installer.

- Plants should be inspected 2-3 times/year for pests, invasive species and re-planting bare areas
- Sporadic weeding may be required if bare patches have developed
- Hand-watering will be required if there is no rainfall during hot temperatures for more than 3 weeks
- Slow release fertilizer, once or twice a year
- Clean/check roof drains 2-3 times per year

CHOOSING FOR LOW MAINTENANCE

The maintenance of plant material is directly related to the following factors:

- Plant species: proper plant selection will eliminate the need for mowing, and rapidly spreading plants will minimize weeding. Most plants can be walked on for maintenance access.
- Initial spacing: the more closely plants are installed initially, the faster they will merge to form a dense mat that will choke out weeds. Proper spacing is dependent on the specie, its propagule and capital cost.
- Plant propagule: plants can be purchased in many forms. Experience demonstrates that plugs are the most cost effective propagule that balances initial capital cost with lower maintenance requirements during the establishment period.
- Pre-grown trays or mats: in spite of a higher capital cost, this planting system eliminates years 1-3 of maintenance.
- Soil medium and depth: shallower soils require greater maintenance because they dry out more rapidly. In soil depth between 2-4 inches, sedums are recommended to stay within the maintenance regime outlined above.

MOLD POTENTIAL

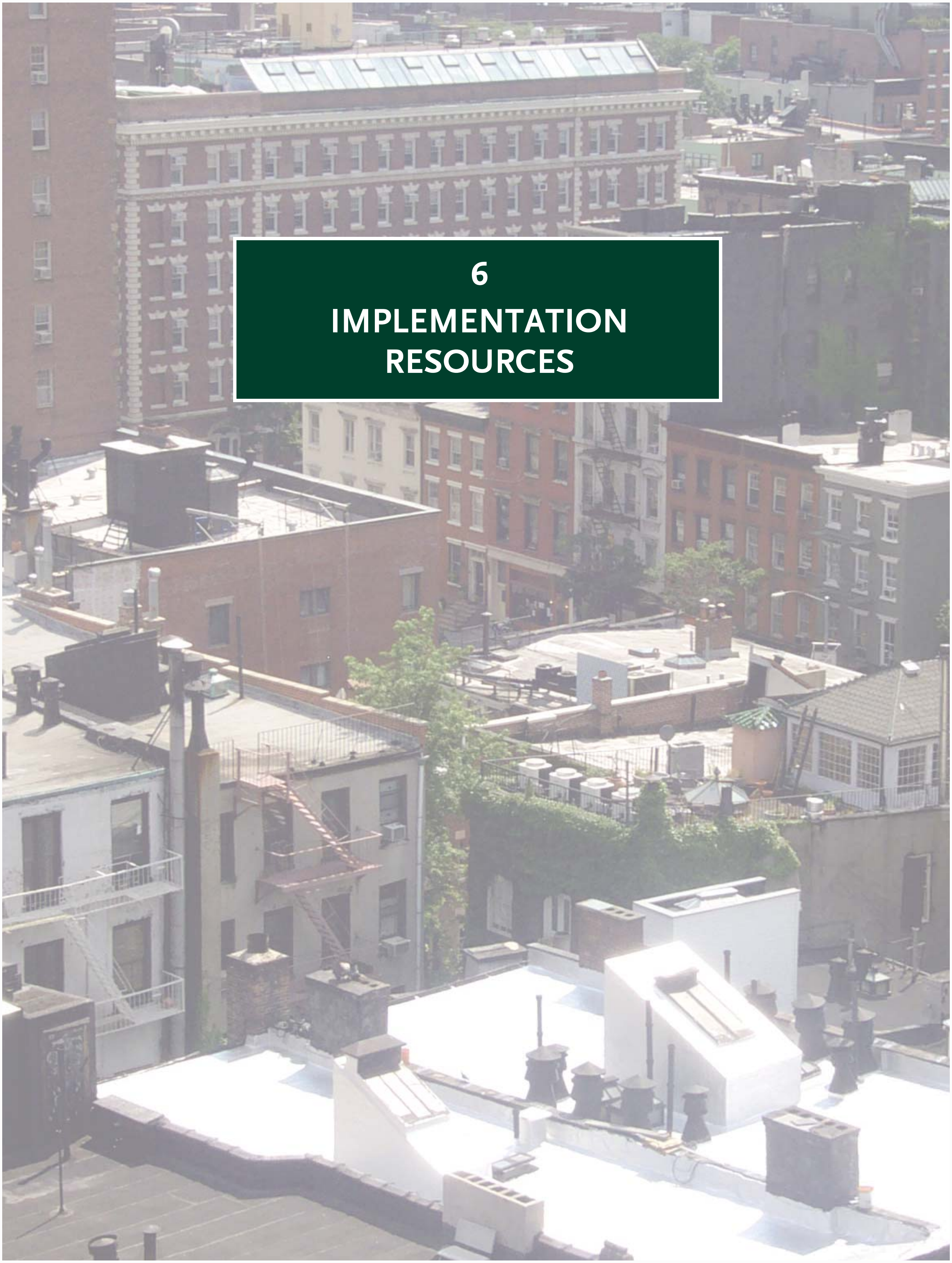
Concerns about mold have been raised in discussions on green roofs, but there is no evidence that green roofs, either modular or continuous, lead to development of mold. This is because of several factors, including good air circulation under modular trays or continuous green roof systems, high mineral composition of the soil medium and temperature of the underlying roof membrane.

PLANT MAINTENANCE— INTENSIVE ROOFS

The plantings on an intensive green roof are more varied, like those in a garden. Maintenance will need to be tailored to the species and design concept. Regular maintenance should be planned, as you would do for a garden. Maintenance tasks include pruning, deadheading, pest control, fertilization and irrigation system monitoring including seasonal adjustment and end of season shut-down.

photo: Mathews Nielsen, Landscape Architects P.C.

Tribeca Green, Manhattan, New York. Roof 4 months after installation.



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IMPLEMENTATION RESOURCES

INTERNET RESOURCES

These governmental and not-for-profit internet resources can supply more information about the urban heat island effect, and may assist your efforts when selecting a cool or planted roof. The list, compiled in June 2004, is certainly not complete; there are numerous other resource web sites, not-for-profit organizations and commercial websites.

FEDERAL RESEARCH AND RESOURCES

http://eande.lbl.gov/HeatIsland/CoolRoofs/ Web site for the Cool Roof program at Lawrence Berkeley National Laboratory, which summarizes their ongoing research on the performance characteristics of cool roofs. The Cool Roofing program is part of LBL's Heat Island Group, and they research the effects of rising urban temperatures and seeks various strategies to mitigate them. Their Cool Roofing Material Database can be reached at **http://eetd.lbl.gov/CoolRoofs/**

http://www.ornl.gov/sci/roofs+walls/ Web site for the Building Envelope Program at Oak Ridge National Laboratory, a research program into energy efficiency and environmental compatibility of both building envelopes and specific materials. The web address to their roof research is **http://www.ornl.gov/sci/roofs+walls/research/reflective.htm** and the address to a Radiation Control fact sheet is **http://www.ornl.gov/sci/roofs+walls/facts/SolarRadiationControl.htm**

http://yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsLocalHeatIslandEffect.html Web site for the U.S. Environmental Protection Agency discussion and resources on Urban Heat Island.

www.epa.gov/nrmrl/news/news042006.html. Website of the U.S. Environmental Protection Agency risk management research on green roofs.

http://www.energystar.gov/index.cfm?c=roof_prods.pr_roof_products Web site for the U.S. Environmental Protection Agency EnergyStar™ program for cool roofs, including the list of qualifying roofing product.

http://roofcalc.cadmusdev.com/ Web site for the U.S. Environmental Protection Agency calculator – a resource that helps consumers estimate energy savings is an EnergyStar roof were installed. Not that this calculator is more useful for residential properties, because it has simplified input and cannot factor in demand charges common for DDC and commercial projects.

http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm Web site for the Cool Roof Calculator developed by the U.S. Department of Energy/Oak Ridge National Laboratory. It estimates the cooling and heating savings when using non-black roofing on flat roofs. This version accepts input of demand charges for peak monthly load.

http://metroeast_climate.ciesin.columbia.edu/. Web site for Climate Change and a Global City: An Assessment of the Metropolitan East Coast Region research, including their assessment report. The MEC Regional Assessment is a joint effort of the Columbia Earth Institute and Goddard Institute for Space Studies. Related web sites are the following: **http://www.earthinstitute.columbia.edu/** and http://www.giss.nasa.gov/

http://www.nrdc.org/water/pollution/rooftops/contents.asp. Website of the National Resources Defense Council, a national non-profit environmental organization. The link opens to a document on stormwater strategies and case studies – “Rooftops to Rivers”.

STATES AND CITIES

http://www.nyc.gov/html/ddc/html/ddcgreen/home.html Web site for the Office of Sustainable Design, Department of Design and Construction ,for the City of New York. Available on the site are the High Performance Building Guidelines, and reports, manuals and sample specifications related to specific topics in the Guidelines.

http://www.energy.ca.gov/title24/ Web site for California’s Title 24 energy conservations standards, with links to the regulations and the inclusion of cool roofs as a compliance options. The related California Energy Commission’s web site on their cool roof program, rebates and resource information is http://www.consumerenergycenter.org/coolroof/index.html

http://egov.cityofchicago.org/city/webportal/portalEntityHomeAction.do?entityName=Environment&entityNameEnumValue=13 Web site of the Chicago Department of Environment’s Rooftop garden program. There are reports on the design, construction, plants and on-going monitoring of the green roof on City Hall. This program is part of Chicago’s City Urban Heat Island Initiative. Guide to Rooftop Garden publication is available on this site.

http://www.sustainableportland.org/ Web site of the City of Portland, Oregon’s Office of Sustainable Development.

http://www.ci.seattle.wa.us/light/conserve/globalwarming/ Web site of the city of Seattle, Washington about Global Warming and city policies.

http://www.seattle.gov/dpd/GreenBuilding/OurProgram/Resources/TechnicalBriefs/DPDS_009485.asp#monitoring Seattle web site with a document link to the Green Roof Evaluation Project.

NON-GOVERNMENTAL AND UNIVERSITY GROUPS

http://www.coolroofs.org/ Web site of the Cool Roof Rating Council, an independent organization that standardizes performance and testing for reflectance and emissivity of cool roofing. The CCRC publishes the data on a directory listing products by manufacturer.

http://www.greeninggotham.org/intro.php. Web site for the Earth Pledge Green Roof Initiative, a New York City organization that promotes green roof in New York, and provides assistance and resources.

http://www.usgbc.org/ Web site of the United States Green Building Council and their Leadership in Energy and Environmental Design (LEED™)

http://hortweb.cas.psu.edu/research/greenroofcenter/ Website of the Penn Sate Center for Green Roof Research, which reports on their programs and research results. This university research is one of the first to conduct research on green roofs in the mid-Atlantic states.

http://www.environmentaldefense.org/documents/493_HotNY.pdf Web site for a 1999 report by the Environmental Defense Fund, Hot Nights in the City, Global Warming, Sea Level Rise and the New York Metropolitan Region (Janinie Bloomfield, Ph.D with Molly Smith and Nicholas Thompson)

http://www.hrt.msu.edu/greenroof/ Website of the Michigan State University for green roof research.

http://www.ssbx.org/ Website for the Sustainable South Bronx, an advocacy group that promotes economic and environmental rebirth for the South Bronx. Projects include the Sustainable South Bronx Smart Roof Project.

http://www.gaiainstituteny.org/Gaia/Green%20Roofs%20at%20St.%20Simon%20Stock.html Website of the nonprofit Gaia Institute, which researches the environment and the integration of human communities.

www.coolcommunities.org Web site of a Georgia-based nonprofit action-oriented advocacy program aimed at improving air and water quality and conserving energy by promoting the use of lighter, reflective (high albedo) roofing and paving materials in combination with strategically planted shade trees as a desirable design "system."

http://www.greenroofs.org Web site of Green Roof for Healthy Cities, a network of public and private organizations that advocates green roofs and provides of forum for sharing information. The web site has information about green roof design and installation, case studies and demonstration projects.

http://www.f-l-l.de/ Web site for the organization in Germany that maintans standards for the design and installation of green roofs. FLL is the Research Society for Landscape Development and Landscape Design (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V.). The green roof guide is titled: Guidelines for the Planning, Development, and Maintenance of Green Roofs (Richlinien für die Planung, Ausführung and Plege von Dachbegrünung). A small part of their site is in English, but most (and standards) are in German.

ROOFING TRADE ORGANIZATIONS

http://www.coolmetalroofing.org/ Web site of the Cool Metal Roofing Coalition.

http://www.roofcoatings.org/ Web site of the Roof Coating Manufacturers Association

http://www.spri.org/ Web site for SPRI, an organization of sheet membrane and component suppliers to the commercial roofing industry

AND OTHERS

http://www.cmhc-schl.gc.ca/en/imquaf/himu/loader.cfm?url=/commonspot/security/getfile.cfm&PageID=32570 Web site for the Design Guidelines for Green Roofs, by Steven Peck and Monica Kuhn. This article was supported by the Ontario Association of Architects and Canadian Mortgage and Housing Corporation (CMHC-SCHL).

The points made in this paper do not represent nor were intended to represent the views of the current municipal administration nor of this agency, but are merely intended to foster discussion regarding initiatives for UHI reduction in NY City.

Reducing New York City's Urban Heat Island Effect

Cost Effectiveness Calculations for White Roofs, Green Roofs, Lighter Roadways and Trees

By Laurie Kerr with Daniel Yao, Office of Sustainable Design, NYC DDC, 2004

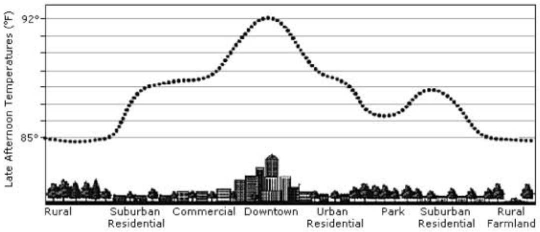
Introduction

Cities are measurably hotter than their surrounding countrysides -- a phenomenon that is known as the Urban Heat Island Effect (UHIE). In 1997-1998[1], New York City was found to be 5.4º to 7.2ºF hotter than nearby rural areas. The city pays a steep price for this in terms of discomfort, increased energy demand and usage, and human health issues, including heat stroke and respiratory illnesses caused by ozone or smog. All of these problems are projected to increase because of global warming.

New York's UHIE results from a lack of vegetation and a preponderance of dark-colored surfaces. Vegetation cools the city by providing shade, by using the sun's energy in photosynthesis, and most of all, by transpiring, which cools by forcing evaporation. On the other hand, dark surfaces, such as asphalt roofs and roads, heat the city by absorbing the sun's radiation and warming up the surrounding buildings and air.

It has been suggested that New York City could potentially reverse the UHIE by planting green roofs, by increasing the reflectivity of its roofs and roads, and/or by planting trees. This paper looks at the cost-effectiveness, in terms of energy savings, of these strategies for the city as a whole. It concludes that it would be very cost effective for the city to start reversing its UHIE by using a combination of the above strategies.

NYC Urban Heat Island Effect. Red (dark) areas are hot.
By: System for World Surveillance

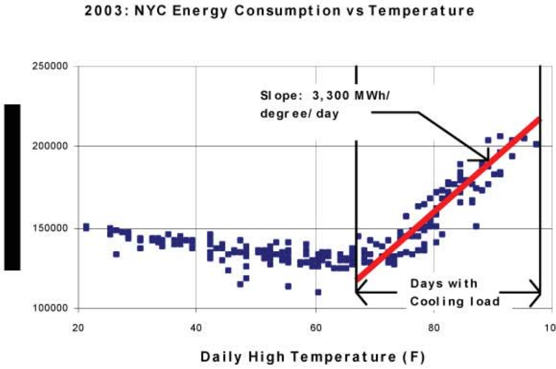


Sketch of an Urban Heat Island Profile
By Heat Island Group of Lawrence Berkeley National Labs.

New York's Energy Consumption Increases with Temperature

How much energy does New York use to cool itself? By plotting the total energy used by the city against daily temperatures, we found that for each degree of temperature increase, the City consumes an average of 3,300 MWh (Megawatt hours) more energy on days when cooling is required[2]. So if we could reverse the Urban Heat Island Effect (UHIE), New York City would save an average of 3,300 MWh/day during the cooling season for every degree saved. Since cooling is required on approximately 150 days annually[3], the annual energy savings for each degree of UHIE reduction would be roughly 495 million KWh.

Given an average cost[4] of 16.5 cents/KWh, the annual cost savings resulting from a one degree decrease of NYC's UHIE would be roughly $82 million.



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1. S.D. Getzelman, S. Austin, R. Cermak, N. Stefano, S. Partridge, S. Quesenberry, & D.A. Robinson 2003: *Mesoscale Aspects of the Urban Heat Island Around New York*, Theor. Appl. Climatol., 75, p 29-42

2. Chart summarizing energy/temp data from NYISO for 2003.
3. Extrapolated from 2004 Flack+Kurtz energy model for DDC's Sunrise Yard project.
4. Conversation with Richard Meilen, Partner; Kallen+Lemelson, (2004)

White Roof Calculations

White (or highly reflective) roofs, which are also known as "cool roofs", could decrease New York city's energy consumption in two ways – one citywide and one at the building scale. The citywide effect would occur if there were enough cool roofs to reverse the UHIE, lowering the entire city's cooling load, as described above. The building-based effects result from cooler roofs on the buildings that have light roofs. This reduces the direct heat transfer into those buildings.

Lawrence Berkeley National Laboratory (LBL) has analyzed the effects of lighter roofs and pavements and additional trees on the UHIE in the Los Angeles metropolitan area, and this paper uses their conclusions as a starting point for thinking about New York. Obviously the climate and physical forms of the two cities are very different. Differing base climates shouldn't affect the UHIE impacts because the UHIE represents a deviation from a base climate due to urban impacts, and we are only analyzing the deviation. Differing forms, however, should affect the magnitude of the UHIE as well as the impact of mitigating measures, and we have tried to account for these differences in our analysis.

LBL calculated that if all the roofs in the Los Angeles region were cool, it would lower the UHIE by 1°F[5]. LBL estimates that roofs comprise 12.5% of Los Angeles' surface area, and from GIS surveys we find that New York is surprisingly similar – with 11.5% of its area being roofed. Therefore, we will assume the 1°F UHIE would hold for New York, if it used cool roofs everywhere. The additional cost of white roofs is $0.68 per sq. ft[6] on average, so, given New York's total of 944 million sq. ft. of roof[7], it would cost roughly $642 million to "cool" all of New York's roofs, reducing the UHIE by one degree. The city would save $82 million dollars per year in avoided cooling costs due to this one degree reduction in the UHIE.

In addition, there are the building-based impacts of white roofs. A DDC energy model of a New York building demonstrated that older buildings with white roofs would save an average $0.036 per square foot per year. However, new buildings with white roofs would only save $0.013 per square foot per year[8], because they have more insulation and more efficient systems. It turns out that 94% of New York's buildings pre-date 1980[9], so the average savings that combined both new and old buildings is roughly $0.032 per square foot per year. If all the roof area in New York were white, but only 75% of the buildings are air-conditioned[10], the building-based savings would be $0.032/sf/yr X 944 M sf X 75% = $23 million/year.

The annual energy savings resulting from both building-based and citywide impacts of white roofs totals $105 Million. The payback period on the $642 million investment in a citywide white roof program would be roughly six years.

[5] Akbari, H. 1996. *Policies to Reduce Heat Islands: Magnitudes of Benefits and Incentives to Achieve Them.* LBL-38679. Berkeley, Calif. Lawrence Berkeley National Laboratory.

Estimated Cost Per Sq Ft of Roofs		
	WhiteRoof Type	**Cost Difference**
Built-Up Roof (base case)	White Mineral Cap	$0.80
	White Coating	$1.00
	Aluminum Coating	$0.80
	White Marble Ballast	$0.50
	White Membrane	$0.30
Average		$0.68

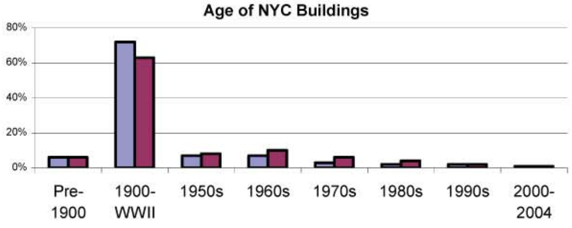
[6] From DDC Draft Cool & Green Roofing Manual, 2004

New York City Area Statistics		
		Percentage
Total Area of NYC	8,238,500,000 sq. ft.	100%
Number of Buildings	837,181	
Roof Area	944,300,00 sq. ft.	11.5%
Gross Building Area	4,895,600,000 sq. ft.	
Avg. Building Height	5.2 stories	
Road Area	1,964,000,000 sq. ft.	23.8%
500,000 Street Trees	157,000,000 sq. ft.	1.9%

[7] From Columbia GSAOO GIS 2204 and NASA/Goddard

Estimated Savings Per Sq Ft of Roof Per Year		
	New Buildings	**Old Buildings**
Built-Up Roof (base case)		
White Roof	$0.028	$0.067
Aluminum Coating	$0.006	$0.021
White Granular	$0.007	$0.023
White Gravel	$0.010	$0.029
Standard Seam Metal	$0.013	$0.039
Average	$0.013	$0.036

[8] From DDC Draft Cool & Green Roofing Manual, 2004



[9] From Columbia GSAPP GIS
First bar represents % of roof area. Second bar represents % of gross building area.

[10] http://www.eia.doe.gov/emeu/reps/appli/mid_atl.html

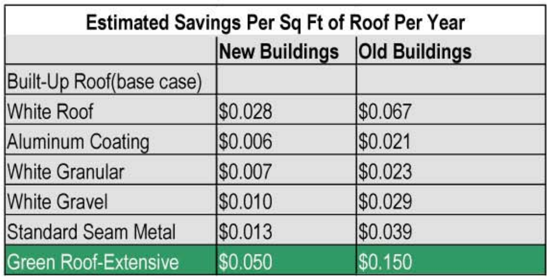
Green Roof Calculations

Green roofs could also provide energy savings to the city through both building-based and citywide impacts. Again the building-based effect would result from the reduced cooling loads on the buildings that have green roofs, because the roofs themselves stay cooler. And again the citywide effect would occur only if enough green roofs were installed to reverse the UHIE, cooling the city as a whole.

NASA/Goddard Space Institute[11] has calculated that if half the roofs of New York City were planted with extensive green roofs, the Urban Heat Island Effect could be reduced by 1°F-1.4°F. (We'll use an average figure of 1.2°F for our calculations.)

The cost of extensive green roofs (above standard roofs) is roughly $10/sq. ft[12]. New York City has 944 million sq. ft[7]. of roof, so the cost to "green" half of New York City's roofs would be roughly $4.72 Billion. If, as NASA has determined, this reduces the UHIE by an estimated 1.2°F, the annual citywide energy-cost savings due to reduced Heat Island Effect would be: $82 Million/degree x 1.2°F = $98.4 Million.

DDC commissioned an energy model of the building-based effects of green roofs on building energy consumption. It showed that older[13] buildings with green roofs would save $0.15 per square foot per year, while newer ones would save only $0.05 because of more efficient equipment and better insulation. Since New York is predominantly old[9] (94% of New York's buildings pre-date 1980) the average savings is roughly $0.144 per square foot per year. If half of NYC's 944 Million sq. ft. of roof area becomes green roof, and 75%[10] of those buildings are air-conditioned, the direct savings to buildings would total $51 Million per year. Adding the building-based and citywide savings, we obtain a total annual energy savings of $149.4 Million for "greening" half of New York City's roofs. Since the cost to green those roofs is roughly $4.72 Billion, the payback period is roughly 31.6 years.



Estimated Savings Per Sq Ft of Roof Per Year

	New Buildings	Old Buildings
Built-Up Roof(base case)		
White Roof	$0.028	$0.067
Aluminum Coating	$0.006	$0.021
White Granular	$0.007	$0.023
White Gravel	$0.010	$0.029
Standard Seam Metal	$0.013	$0.039
Green Roof-Extensive	$0.050	$0.150

11. Green Roofs in the NY Metropolitan Region, 2004

12. From DDC Draft Cool & Green Roofing Manual, 2004 and Conversation with American Hydrotech (2004)

13. From DDC Draft Cool & Green Roofing Manual, 2004

Roadway calculations

The LBL study[5] found that if the asphalt roads in Los Angeles were replaced with concrete, which is more highly reflective than asphalt, the UHIE would be reduced by roughly 0.6º F. It's difficult to extrapolate this to New York City, since the physical urban forms are so different. But for the purposes of argument, let's assume all effects are roughly linear. Roadway covers 23.8% of NYC's surface area[7] as opposed to 12.5% for L.A[14] -- a factor of 1.9 increase. So if New York's roads were to be resurfaced in concrete, we might expect and UHI reduction of roughly .6º F x 1.9 = 1.14º F.

Because of the need for frequent access to underground utilities, it would not be practical to use concrete for New York's roadways, so we will consider the impact of using white aggregate in the asphalt mix instead of using concrete. The impact of switching to white aggregate in asphalt is roughly .6 times as effective as switching to concrete (see sidebar), resulting in a 1.14º F x 0.6 = 0.7º F estimated drop in New York's UHIE.

Switching to white aggregate would increase costs by less than $0.03 per sq. ft. of roadway[18]. NYC has 1.964 Billion sq. ft. of road[7], so the additional cost of resurfacing New York's roads using light colored aggregate would be approximately $59 Million.

The only energy savings from light colored roadways are the citywide savings related to the UHI reduction. A 0.7º F UHIE drop results in 0.7 x $82 million = $57.2 million in annual savings, resulting in a payback of slightly more than one year.

Reflectance Calculations for Roadway Surfaces:

From LBL, we obtain the following approximate data[15, 16]: the aged reflectance of concrete is 0.25, the aged reflectance of asphalt is 70% of the reflectance of its aggregate, and the reflectance of currently standard aged asphalt is 0.12. So, by replacing standard asphalt by concrete, the reflectivity of the roadway would increase by 0.25 – 0.12 = 0.13.

White marble aggregate has a reflectivity of roughly .28 (obtained by averaging its initial and aged reflectance)[18]. So if white aggregate replaces standard aggregate the reflectivity of the roadway would increase by (.7 x 2.8) – .12 = 0.08. Thus, we can estimate that the relative effectiveness in UHI reduction of using white aggregate in asphalt instead of concrete might be a factor of roughly .08/ .13 = 0.6.

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[14] *Painting the Town White – and Green*, by Rosenfeld, Romm, Akbari, & Lloyd, LBNL; http;://eetd.lbl.gov/Heat Island/PUBS/PAINTING

[15] M. Ting, J. Koomey, & M. Pomeranz, *Preliminary Evaluation of the Lifecycle Costs and Market Barriers of Reflective Pavements*, Nov. 2001; LBNL-45864; http://enduse.lbl.gov/Projects/pavements.html

[16] M. Pomerantz, B. Pon, H. Akbari, and S.C. Chang, The Effect of Pavements' Temperatures on Air Temperatures in Large Cities, 2000, LBNL-43442; http://eetd.lbl.gov/HeatIsland/PUBS/200/43442rep.pdf

[17] From DDC Draft Cool & Green Roofing Manual, 2004

[18] Internal communication from DDC Infrastructure group, 2004 and LBL op cit, Note 5.

Tree calculations

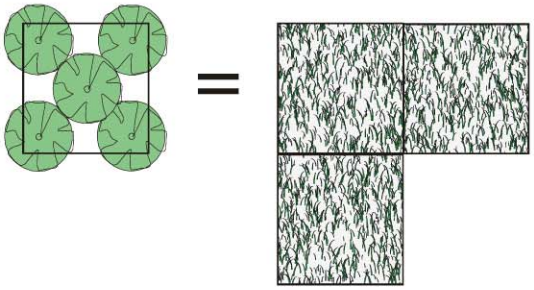
Compared to an equivalent area of extensive green roof, a mature maple tree is four to five times as effective in providing cooling through evaporative transpiration[19], but it is equally effective in providing cooling through shading. Assuming that the UHIE reduction is due partly to transpiration and partly to shading, we might average the two -- and this is somewhat speculative -- resulting in an estimated increased effectiveness of a factor of three for sq. ft. of tree over sq. ft. of green roof.

Assuming an average crown width of 20', or 314 sq. ft. per New York street tree, the number of trees required to mimic the 1.2° F UHIE reduction created by extensive roofs (above) would be roughly 472 Million sq. ft. x 0.333 ÷ 314 sq. ft. per tree = 500,000 trees. Incidentally, this is roughly the number of New York's current street trees and one tenth of NYC's estimated canopy, or total area of tree coverage [20].

If all the added trees are street trees located in existing sidewalks, we must include the cost of sidewalk cutting and soil removal. (The cost of planting trees elsewhere would be less, but this analysis uses street trees because they are in the public right-of-way.) Currently, it costs $750 to plant a NYC street tree, but if larger linear tree pits were used along with structural soils, the price might climb to $1,250[21] per tree. Let's assume the higher figure, since these improved methods would help ensure that the trees will reach maturity and provide the UHIE reduction. The cost of 500,000 well-planted trees would be $625 million, and the annual citywide energy savings due to reduced UHIE would be $98.4 Million, as it was for green roofs.

In addition, there is a local cooling effect on buildings that are shaded by these trees, which would result in an annual savings $4.4 million (see Text Box).

The local and city-wide impacts add up to energy savings of $103 million per year, or a payback period of slightly more than six years.



Trees can provide the same amount of cooling as extensive green roofs using roughly one third of the area.

Energy Impacts of Tree-shading:

A Sacramento study[22] found an average annual savings153 kWh per tree due to direct shading in a residential area. It's hard to translate this to NYC, since NY's trees are smaller and the neighboring buildings already provide some shade. On the other hand, NYC's buildings are older and less efficient, which would tend to increase the savings. Let's assume that all the effects except for tree size cancel each other out, that New York's smaller trees provide roughly half the shade of Sacramento's larger trees, and there is a winter heating penalty of 30%. Thus each tree would result in an annual savings of 153 kWh x 0.5 x $0.165 / kWh x 0.7 = $8.80 per tree, or $4.4 million annually for the 500,000 trees.

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[19] Communication with Chris Wark of SHADE Consulting, 2004

[20] As of 2002, Information from David Nowak of USDA Forest Service; NYC Dept. of Parks and Recreation

[21] Internal communication: DDC Architecture and Engineering – Landscape Architecture Group, 2004

[22] *Simulation of Tree Shade Impacts on Residential Energy Use for Space Conditioning in Sacramento*, Simpson and McPherson, Atmospheric Environment, Vol. 32, No 1, pp 69 – 74, 1998

Conclusions

According to these rough calculations, using light colored aggregate in roadways is very cost-effective in reducing the Urban Heat Island Effect, since it pays for itself in less than a year. Street trees and light colored roof surfaces are also quite cost-effective, with payback periods in the six year range. Green roofs have the longest payback – roughly thirty years.

These calculations include only energy savings, ignoring a host of other benefits, many of which could provide savings well in excess of the energy savings. Reducing the UHIE would not only make the city more livable, it would improve public health through a decrease in smog, heat-related illnesses, and the number of vector-borne diseases. It would also lower peak energy demand, reducing the need for new power plants, pollution, and the frequency of brown-outs.

The street level improvements – lighter asphalt and more trees – are public amenities that improve the streetscape and put cooling where the pedestrians are – important considerations in a city that depends on pedestrians and public transportation. Green roofs may prove to pay for themselves if it can be proven that they appreciably extend the life of the roofing membranes. Finally, greening strategies, such as green roofs and trees, have benefits in terms of air purification, reduced runoff, CO2 sequestration, and perhaps most importantly, greenery vastly increases the desirability and livability of cities, which ultimately counteracts the impulse toward sprawl. Putting numbers to these additional effects would be extremely useful.

Even if we limit ourselves to the cost savings due to energy, there is ample evidence to support a public policy of providing whiter aggregate in roads, additional street trees, and cool roofs, excluding green roofs because of their longer payback period.

Let's imagine the city embarked on a twenty-year plan to plant 500,000 street trees and to replace all of its roofs with cool roofs and its road surfaces with asphalt with lighter colored aggregate. (A twenty year schedule makes sense because roofs and roadways are replaced roughly every twenty years.) In twenty years New York's UHIE would have been reduced by roughly 2°F, growing to 2.8°F aver the next thirty years, as the trees reached maturity. This would represent a reversal of 40% to 50% of NYC's Urban Heat Island Effect.

Considering only the energy savings, the payback period for the combined measures is 5 years, with a cost to the city of $66 Million annually. These figures are conservative. If other impacts were considered, particularly the improvements in public health, the payback period would be dramatically reduced.

Summary of the Cost/ Benefit of Strategies[a]

Strategy	Annual Cost over 20 years	Annual Energy Savings	Average UHIE Reduction	Payback
1. White Roofs	$32 million	$105 million[b]	1.0 deg. F[b]	6 yrs. [b]
2. Light Aggreg.	$3 million	$57 million[b]	0.9 deg. F[b]	1 yr. [b]
3. Street Trees	$31 million	$70 million[c]	0.8 deg. F[c]	6 yrs.[d]
Combined: 1,2,3	66 million[c]	$232 million[c]	2.7 deg. F[c]	5.7 yrs. [c]

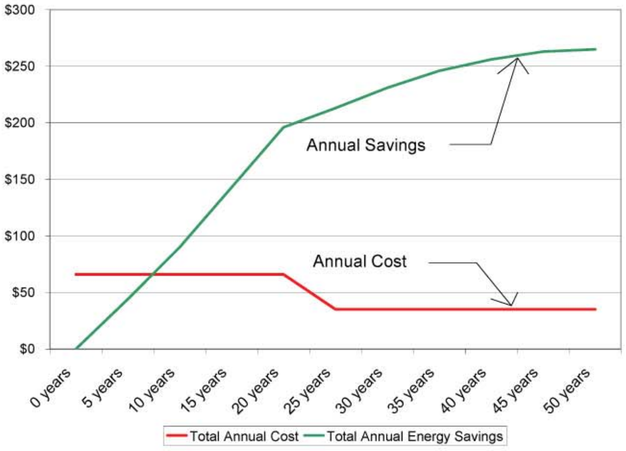
Notes:

a. Note that the annual energy savings for Strategies 1,2, and 3, as well as the combined strategy, greatly exceed the annual cost for installation. This means that over time the annual cost savings will eventually exceed the expenditures as the anti- UHIE measures become effective. See graph below showing the annual cost outlays and the annual energy savings over 50 years.

b. Calculated after 20 years, when all of the roofs are cool and all the roads have light aggregate.

c. Calculated after 30 years when the first of the trees to be planted are reaching maturity. Since the trees are growing, their impact varies over time, from roughly 0.4°F after twenty years, to 0.8°F after 30 years, to 1.2°F after 50 years, when all the trees have matured.

d. Payback has been calculated for fully mature trees.



Annual Costs and Savings (in $millions) over 50 Years
(in 2004 dollars)

How Could This Be Funded?

Who will pay for this, when the savings would be divided among the many public and private entities that purchase energy in the city, and the interventions required would affect both private and public properties?

Starting with the street trees, it should be noted that some of the increase in the city's tree canopy has already been budgeted by NYC Parks. Also there is an interesting New Jersey model for street trees: a program to plant 100,000 trees in New Jersey has been funded jointly by the NJ Department of Environmental Protection and the Board of Public Utilities.

It is not far-fetched to imagine that New York's utilities and/or the New York State Energy Research and Development Authority (NYSERDA) would pitch in to cover some costs. The city anticipates a 2,600 MW shortfall in electrical generating capacity by 2008[23], which could lead to brown-outs. Reducing the UHIE would lower peak demand and help bridge this gap. Let's assume, then, that New York's utilities will fund half the trees and the city the other half.

Cool roofs could be required by code, as they are in California's Title 24. Requiring cool roofs by code would spread the minimal cost of this measure to the various buildings that would accrue the financial benefits. The city would pay roughly 10% of this expense because it owns roughly 10% of the buildings.

Finally, the minimal cost of lighter aggregate in the roadways would add less than $3 million per year to the city's budget.

The chart to the right summarizes this apportioning strategy, which would result in an annual cost to the city of $21.5 Million over twenty years, ultimately reducing New York City's UHIE by 40% to 50%, and saving $196 million annually, rising to $265 million after 50 years, as all the trees reach maturity.

Apportioning the Annual Costs

Strategy	Annual Cost (over 20 years)	Cost to City	Cost to Utilities / NYSERDA	Cost to Building Owners
1. White Roofs	$32 M	$3 M	$0	$29 M
2. Light Aggregate	$3 M	$3 M	$0	$0
3. Street Trees	$31 M	$15.5 M	$15.5 M	$0
Combined: 1,2,3	$66 M	$21.5 M	$15.5 M	$29 M

The points made in this paper do not represent nor were intended to represent the views of the current municipal administration nor of this agency, but are merely intended to foster discussion regarding initiatives for UHI reduction in NY City.

A Caveat

The calculations presented here are "back of the envelope" energy calculations using available information from GIS data and prior studies. Where information is missing, we have extrapolated and made educated guesses to get a feel for the impact of these strategies on NYC. More research is needed to refine these numbers, and further work will be required to incorporate measurable impacts other than energy – such as health savings, roof longevity, maintenance and water issues.

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23. *New York City Energy Policy: An Electricity Roadmap*, by the NYC Energy Policy Task Force, January 2004

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