Greening Rooftops for Sustainable Communities
conference, awards & trade show
Baltimore, MD
April 30 to May 2, 2008

Session Number: Session Title

COST BENEFIT ANALYSIS OF THE PROPOSED EXTENSIVE GREEN ROOFS PROGRAM IN NEW YORK CITY.

Amy Norquist, M. Levandowsky

Greensulate LLC./Haskins Labs, Pace U., N.Y., NY

Abstract

In April of 2007, Mayor Bloomberg's office released PLANYC, a comprehensive blueprint for making New York City sustainable in the year 2030. In that Plan they recommend an extensive green roofs program as a means to reduce storm water overflows, reduce $C0_2$ emissions, and modify the Urban Heat Island effect. Earlier, a memo from the city's Department of Design and Construction (DDC) came to the conclusion that extensive green roofs may not be cost effective for the City. We examine the various points raised in this memo, as well as others that were not considered, and come to a different conclusion than that of the memo. The memo does not address a number of potentially significant issues, such as potential public health benefits.

Key Words: extensive green roofs; New York City; cost-benefit analysis

Introduction

A number of cities in this country and elsewhere have adopted policies to encourage the use of green roofs. In April of 2007 the City of New York announced a plan and priorities to make the city more sustainable, called PLANYC. One feature of this plan is an incentive to encourage the spread of green roofs. Subsequently, on November 29^{th} and then on December 19^{th}, New York City's Council Finance committee and then the full City Council approved a resolution (#1004) which calls on the New York State Legislature to provide property tax abatement for the installation of green roofs.

Meanwhile, though, a city agency, the Department of Design and Construction (DDC) produced and distributed a memo which presents a somewhat negative view of the economics of urban green roofs. Since this memo was a serious effort, involving many professions, and may indeed reappear when the resolution is presented to legislators in Albany, it has potential impact on the policies of New York and other cities. We feel it is timely and important to examine and evaluate the arguments in the DDC memo.

The Memo

We will first summarize the major points in the memo.

1. Scope: It deals exclusively with extensive green roofs, confining its analysis to environmental issues, to the exclusion of aesthetic, recreational and other amenity-type uses. In particular, the analysis focuses almost entirely on thermal effects - - potential mitigation of the urban heat island effect and possible savings on building energy use for cooling and heating – and possible stormwater retention benefits.

2. Direct effects on energy use by buildings: DDC used a standard building energy model to calculate the savings per square foot from the insulating properties of an extensive green roof, concluding that the pay back time for the extra expense of green roof installation ranged from 50 to 500 years, depending on age and type of building.

3. Potential effects on urban heat island effect (UHIE): Assuming that half of New York City's roofs were green roofs, a climate model by the Climate Group at Columbia University/GIS NASA predicts that the UHIE effect would be reduced by 1 to 1.4 degrees F. Then, considering the city's energy consumption as it varies according to high temperatures, DDC estimates energy cumulative savings of $98 million per year. They contrast this with an estimated installation cost, at $8 –12 per sq. ft, of $6 to $9 billion to cover half the city's roof tops. Combining this with the previous estimate for energy savings in the buildings (#2 above), they estimate a payback time to the city as a whole of 35 to 50 years from thermal properties, noting that costs for maintenance of the roofs were not included in the estimate.

4. Water purification: The memo considers possible stormwater retention benefits. First, DDC considers the possibility of a purifying effect on rainwater discharge. They refer to a single Belgian study done on a model system, which analyzed the effects of several small modular commercial green roof systems on the chemical composition of water draining through the systems. The brownish drainwater contained organic and mineral components, possibly from fertilizer, as well as microorganisms. They cite also anecdotal accounts of problems encountered in Seattle using gray water from a green roof to flush toilets, which became discolored.

5. Storm water retention (1): Regarding problems of storm water and combined sewage overflow (CSO) draining into nearby waters, they note that new buildings in New York City are now required to retain storm waters on site and release them slowly. Thus, the potential benefit of retention of water by a green roof would be minimal for new buildings – at most they might allow some decrease in the mandated retention systems.

6. Storm water retention (2): For old buildings, lacking such retention systems, green roofs would decrease the amount of storm water released. Lacking data, DDC uses an estimate that less than half of the water from major storm events would be retained by a green roof. This leads to an estimate that, if half of NYC buildings had green roofs, runoff would be diminished by 4.5% at most. It is suggested that other water retention and absorption methodologies, such as porous paving, cisterns and increased planting at grade, appear to hold more promise.

7. Biodiversity: Finally, the memo suggests that the thin layer of growth medium of an extensive green roof system precludes consideration of it as wildlife habitat or for urban farming.

Given these arguments, the memo concludes that (1) green roofs are not a cost-effective way to reduce building energy consumption or the urban heat island effect (UHIE); (2) storm water retention needs more study but is not promising; (3) if a green roof program were to be instituted, there would added bureaucratic system requirements for permitting, inspection, record-keeping, etc.

In summary, the DDC memo is pessimistic regarding the cost-benefit potential of a green roof program for New York City. Let us now consider some of the points raised as well as information and situations specific to New York City that should be considered in the cost/benefit analysis of green roofs. We use here the same numbers as above, with primes added, to provide a concordance between the points raised and our discussion.

Analysis of the Memo

1'. Scope: Some potentially significant effects are not considered in the memo but need to be included in any calculation of cost-benefits. The most significant may be the benefit from prolongation of the lifetime of a roof (Porsche and Koehler 2003). The growth media and plants of a properly installed green roof protect the roof membrane from solar ultraviolet radiation and from the stresses of temperature extremes. The experience is that the lifetime of a green roof is at least 20 years longer than that of a typical asphalt roof, and there are green roofs in Germany that are 90 years old and have not yet needed replacement or significant repairs (e.g., Saiz et al 2005).

Another potentially significant aspect missing in the memo is air quality and its effects on public health. This was studied recently by Clark et al (2006, 2008). In particular, one of the major pollutants of concern, NOx (nitrogen oxides), produced by automobile traffic in urban habitats such as NYC, is absorbed by plants and this could mitigate a major cause of human respiratory disease (Saxe 1986, Takahashi et al 2005, Morikawa et al 32). The effects of this mitigation can be significant from a public health viewpoint, and can be translated into medical cost estimates using USEPA guidelines. Details of the calculations can be found in Clark et al (2008). However, much more data, from green roof plants in field studies, are needed to accurately assess this effect. Other air pollutants of concern, such as ground-level ozone, may be absorbed by green roof plants and research in this area is greatly needed.

Aside from the air quality benefits associated with reducing the urban heat island, green roofs filter particulate matter from the air and absorb greenhouse gases. Though little research has been done to quantify the air filtration capacity of green roofs, by one estimate one square meter of grass roof can remove approximately .22 lb/year (0.1kg/year) of airborne particulates (GRHC, 2002). Gasoline fueled passenger vehicles typically produce on the order of 2.5x10-5 lb (.01 g) of particulate matter per mile oftravel.2 Assuming 10,000 miles are driven by a vehicle in a year, that's .22 lb (0.1 kg) of particulate matter per year. Thus, one square meter of green roof could offset the annual particulate matter emissions of one car (City of Los Angeles, 2006).

Other potential benefits not considered by the memo include sound insulation and fire retardant properties, both potentially significant benefits in the urban setting. Green roofs have proven to be an effective form of noise reduction. Tests have indicated that 5 inches of growing medium can reduce noise by 40 Db (Peck, et al 2001). The green roof at GAP Inc. Headquarters in San Bruno, CA is said to decrease noise level by up to 50 Db, an important consideration given that the building is located just a couple miles from San Francisco International Airport. Fire retardant benefits are also possible. The early green roofs in Germany were in fact developed as fire-retardant structures on asphalt roofs.

Regarding comments in the memo on aesthetics and other amenity values, it should be noted that green roofs can be visually quite striking, as seen in examples from the compendium by Earth Pledge (2005).

Lastly, the issues that are unique to New York (and possibly other major metropolitan areas) include the cost and logistical difficulty of public work projects such as sewage system repair and storage. The New York sewer system is over 160 years old, in places passing through sewer drainage conduits made of brick and mortar. The water that enters the city for public use—1.2-2 billion gallons— is pumped 24-hours a day through two giant tunnels originating in reservoirs outside the City. They can never be closed due to the extraordinary continuous demand. A new tunnel is being built so that tunnels can occasionally be closed for maintenance, and to satisfy ever increasing demand. Building such tunnels is expensive and difficult. This third tunnel, when operational, will result in increased water flow into New York's sewage system, which is already running behind on capacity.

A significant event related to NYC critical sewer system was the subway system tunnels flooding of August, 8, 2007: The shutdown of NYC's subway lines was more than a major hassle to millions of New Yorkers, it also cost the taxpayers millions of dollars. Governor Spitzer was immediately critical of the MTA pointing out that "this was the third time the transit system failed in the last seven month due to weather, costing taxpayers millions of dollars." Given that weather issues aren't going away, an MTA report was requested and completed. Its conclusions were not promising. The report identified flood prone areas (basically all of areas that flooded in August and then some) and said based on current sewer design criteria they will continue to flood during period s of intense rain. Even if the subway pumps were working harder and faster there is not enough capacity within the system to take it out of the station. (MTA, 2007) "There is only so much water the sewers and subway can handle" said NYC DEP commissioner Emily Lloyd. “When it comes down faster you just can’t get a catch basin or sewer pipe fast enough.”

Thus we suggest that the strain on and age of sewage and transit systems warrants investing in storm water management as part of the essential solution to reduce flooding.

2’. Direct effects on energy use by buildings: There is a major problem with the memo in regard to analysis of building energy use. The model they use was developed by national laboratories and is well-tested for typical conventional building thermal regimes. What’s significantly different in a green roof building, and not captured by the standard models, is the active cooling by evapotranspiration. The building energy simulation model EnergyPlus v2.0.0, (released April 2007), available from the US Department of Energy, has a green roof component called *ecoroof,* but this does not account for the dominant nonlinear effect of evapotranspiration from substrate and plants. Essentially, the plants and substrate on a hot day are acting as air conditioners, and this effect can be significantly greater than simply the albedo effect of, say, a white roof. This has been shown by recent experimental and modeling studies by Dr. Berghage at Pennsylvania State University, and Dr. Gaffin and the group at the Columbia University Climate Center, and others (Gaffin et al 2005, 2006). Also, green roofs provide their greatest benefit during very hot weather that tends to coincide with peak energy demand--for air conditioners--and thus peak costs. It would be interesting to explore models that look at the correlation between the east coast blackout of ’03 and a hypothetical scenario of New York City and other eastern urban centers with substantial green roof cover.

3’. Potential effects on urban heat island effect (UHIE): The figure cited in the memo can be compared to that from a regional simulation model for Toronto. Using 50% green roof coverage, Bass et al (2002) found a greater cooling effect, up to 3.6 degrees F. It should be noted that the greatest cooling effects come at the highest temperatures. During an extremely hot period, the public health effects of even a single degree F can be substantial.

4’. Water purifying effect. Clearly, water passing through a green roof system will pick up organic and inorganic materials from the plants and the growth medium, particularly in the initial stages when some fertilizers may be used. Unfortunately, the Belgian study cited in the memo didn’t measure nitrogen compounds, which would be of most concern for New York inshore waters, where nitrogen tends to be the limiting ecological factor for phytoplankton blooms. There are some useful data from a study in North Carolina (Moran & Smith 2005), but it’s clear that more research is needed in this area.

While it is wrong to say that water passing through a green roof is purified, it is changed. One of us (ML, unpublished data) measured water quality in rainwater before and after passing through modules of growth media and *Sedum* plants during the major rain events of summer, 2007 on a rooftop in lower Manhattan, New York City. There were major changes in pH. Rainwater during the summer was acid, with pH ranging from 3.7 to 5.7, but after passing through the growth media it was always neutral (pH 7.0-7.1). Given that rainwater is typically poorly buffered, it’s not clear if this would have a significant effect on the local saline waters of the Lower Hudson and East Rivers, but the effect clearly needs more study. On some occasions rainwater contained low levels of ammonia, which was absent in water draining from the growth medium. In our experience the drain water was always brown, and no doubt had organic and other materials in it. Most likely it would not be suitable for use in flushing toilets, but it might well be useful for horticultural purposes. Thus, preliminary observations suggest the possibility that the green roof might mitigate acid rain, and it is also possible that pollutants in the rainwater could be removed. More work on this is clearly needed.

Green roofs can indirectly affect the entry of heavy metals, nitrate, diesel soot, volotile organic compounds (VOCs), hydrocarbons and pesticides into local waters by decreasing CSOs. CSOs are also the largest single source of pathogens in New York Harbor and as a result NYCDEP is under Consent Order to spend hundreds of millions of dollars per year toward CSO abatement. (NYCIBO, 2004).

5'. Storm water retention (1): As the memo notes, new buildings in New York City are required to store excess runoff to prevent CSO. The extent to which green roofs could make this easier (i.e., require storage of less volume) needs to be studied.

6'. Storm water retention (2): Urban runoff and stormwater management is one of the most researched areas in terms of green roof benefits. Given that over 80% of New York City is served by combined sewer systems, when the stormwater loads are too great to be captured by these systems the resulting CSO's (28 billion gallons a year into NY Harbor) are the largest source of pathogens in NY Harbor. (Montalto et al, 2007) And given that urban runoff tends to be a local effect of a given watershed, the significance of mitigation by green roof absorption, needs to be gauged on a case by case level. In some parts of the city as little as 1/20th an inch of rain can trigger an overflow, far less than the "major storm events" referred to by the DDC (NYSDEC, 2001). In the drainage area for Gowanus Canal, (Montalto et al 2007) conclude that 90% of all row houses in this area can support green roofs.

Montalto et al (2007) studied a specific drainage area within New York City, the Gowanus Canal Drainage, which is the CSOSHED for a large swath of Brooklyn. They conclude that as much as 50% reduction in combined sewage overflows could be achieved in this CSOSHED by an $80 million investment in green roof technology.

Thus, the overall figure regarding CSO's and green roofs given in the DDC memo may not be very meaningful.

7'. Biodiversity: Regarding the question of wildlife, it's worth noting that several studies have followed the fauna of extensive green roofs (Baumann 2006, Kadas 2006, Gedge & Kadas 2004), so this may not be an insignificant effect, though perhaps difficult to include in economic models. In the case of our lower Manhattan study, we frequently observed butterflies and solitary bee species when the plants were in bloom. Plant diversity also can be impressive in these simple systems (e.g. Koehler 2006).

Conclusions

Clearly it is a useful exercise to examine the points in a serious criticism. Even if the criticism is not supported, the examination leads to greater insight. In the present case, we reach the view that the negative conclusions of this memo are in fact not well-supported by current data and analysis, but to be fair, much of the relevant research noted here has appeared since the memo was written.

One point raised by the memo that seems worth further analysis and consideration is the suggestion that a green roof program would carry an added bureaucratic burden, for permitting, inspection and enforcement. Another aspect needing consideration is maintenance. Extensive green roofs are designed to required minimal maintenance, but there would be issues arising regarding cost here. For example, would additional training be required of building superintendents?

For a good recent summary of current research on Green roof properties and benefits we recommend the review by Oberndorfer et al (2007). This paper also helps clarify the importance of local watershed evaluation as a key component in developing realistic cost/benefit models for green roofs.

Acknowledgement: M. Levandowsky was supported by a grant from the USEPA.

References

Bass, B, Krayenhoff, ES, Martilli, A, Stull, RB & Auld, H, 2003, ‘The impact of green roofs on Toronto’s urban heat island,’ Proceedings of the first Annual Greening Rooftops for Sustainable Communities Conference, 20-30 May, Chicago

Baumann, N. 2006, ‘Ground-nesting birds on green roofs in Switzerland: preliminary observations. Urban Habitats, vol. 4, pp. 37-50.

City of Los Angeles, Environmental Affairs Department, 2006 Report: Green Roofs-Cooling Los Angeles.

Clark, C, Adriaens, P & Talbot, FB 2006, ‘Probabilistic economic analysis of green roof benefits for policy design,’ Proceedings of the 4th Annual Greening Rooftops for Sustainable Communities. Boston, MA May 10-12, 2006

Clark, C, Adriaens, P & Talbot, FB 2008, ‘Green roof valuation: A probabilistic economic analysis of environmental benefits’ Environmental Science and Technology, *In Press*.

Earth Pledge, 2005, Green roofs: ecological design and construction. Schiffer Books, Atglen, Pennsylvania 19310

Gaffin, S, Rosenzweig, C, Parshall, L, Beattie, D, Berghage, R, O'Keefe, G & Brman, D, 2005, 'Energy balance modeling applied to a comparison of green and white roof cooling efficiency.' Proceedings of the Third Annual Greening Rooftops for Sustainable Communities Conference, 4-6 May, 2005, Washington, DC

Gaffin, S, Rosenzweig, C, Parshall,L, Hillel, D, Eichenbaum-Pikser, J, Greenbaum, A, Blake, R, Beattie, R & Berghage, R 2006, 'Quantifying evaporative cooling from green roofs and comparison to other land surfaces.' Proceedings of the 4t^{h} annual Greening Rooftops for Sustainable Communities Conference. 11-12 May 2006, Boston.

Gedge, D & Kadas, G, 2004, Bugs, bees and spiders: Green roof design for rare invertebrates. Proceedings of the second Annual Greening Rooftops for sustainable Communities Conference, Portland, OR

GRHC, 2002. "Public Benefits of Green Roofs". The Cardinal Group Inc., Green Roofs for Healthy Cities. Toronto, Ontario Canada.

Heaney, JP; Pitt, R and R. Field. 1999. Innovative Urban Wet-Weather Flow Management Systems. EPA/600/R-99/029, available at http://www.epa.gov/nrmrl/pubs/600r99029/600R99029prelim.pdf.

Kadas, G, 2006 'Rare invertebrates colonizing green roofs in London.' Urban Habitats vol. 4, 66-86.

Kerr, L, 2006, 'The cost effectiveness of green roofs as an environmental strategy,' Memo. March 8 2006, New York City Department of Design and Construction, N.Y., NY

Koehler, Manfred 2006 'Long-term vegetation research on two extensive green roofs in Berlin.' Urban Habitats vol4, 3-26.

Montalto, F. Behr, Alfredo, Wolf, Arye and Walsh, 2007: Rapid assessment of the cost-effectiveness of low impact development for CSO control. Landscape and Urban Planning 82 (2007) 117–131.

Morikawa, H, Takahashi, M &Kawamura, Y 1998, More than a 600-fold variation in Nitrogen dioxide assimilation among 217 plant taxa. Plant Cell Environment 1998 vol 21, pp. 180-190

MTA, 2007. August 8th Storm Report to Governor Spitzer.

New York City Council Web site: http://webdocs.nyccouncil.info

New York City Independent Budget Office, 2004. City's 17 billion Water and Sewer Plan-Balancing Risks and Costs. IBO Fiscal Brief May 2004.

Oberndorfer, E, Lundholm, J, Bass, B, Coffman, RR, Doshi, H, Dunnett, N, Gaffin, S, Koehler, M, Liu, KKY & Rowe, B, 'Green roofs as urban ecosystems: ecological structures, functions, and services,' 2007, BioScience vol. 57, no. 10, pp. 823-833.

Peck, S., & Kuhn, M., (2001). Design Guidelines for Green Roofs. Ontario Association of Architects and Canada Mortgage and Housing Corporation.

Porsche, U & Koehler, M 2003 'Life cycle costs of green roofs: A comparison of Germany, USA, and Brazil.' Proceedings of the World Climate and Energy Event, 1-5 December 2003, Rio de Janeiro, Brazil.

Saiz, S, Kennedy, C, Bass, B &Pressnail, K, 2006, comparative life cycle assessment of standard and green roofs. Environmental Science and Technology vol. 40, pp. 4312-4316.

Saxe, H 1986, Stomatal-dependent and stomatal-independent uptake of NOx. New Phytologist vol 103, pp. 199-205.

Takahashi, M, Konaka, D, Sakamoto, A & Morikawa, H 2005, Nocturnal uptake and assimilation of nitrogen dioxide by c3 and CAM plants. Zeitschrift für Naturforschung, vol. 60c, 279-284