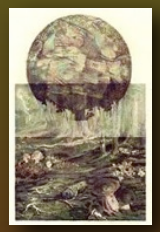
GREEN ROOFS
For Healthy Cities

Integrating Stormwater and Greywater Treatment for Thermal Regulation and the Enhancement of Biological Diversity: Using Mass Balance of Water as a Design Criteria

Paul S. Mankiewicz, Ph.D.
Daniel B. Simon, LEED AP
The Gaia Institute
April 30, 2007

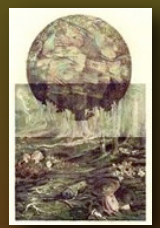


The Gaia Institute

Quantification of 'The Snodgrass Rule' of green roof construction schedules

To estimate actual construction start date,
take the outside limit of the number of days to construction

- For pre-existing roofs: multiply by 5 to 7;
- New construction: multiply by 10+
- (Uncertainties are proportional to the numbers of contractors, agencies, and other public and private entities involved)



The Gaia Institute

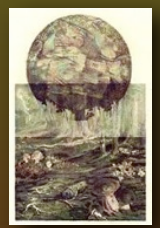
Stormwater as wastewater

Many a man curses the rain that falls upon his head, and knows not that it brings abundance to drive away the hunger.

- Saint Basil

Problems caused where stormwater is treated as wastewater:

- Combined sewer overflow
- Incurs cost of wastewater treatment
- GHG emissions at wastewater treatment plants
- Thermal shock to receiving waters



The Gaia Institute

The Costs of Water
No Incentive to capture stormwater onsite

New York City combines:
(a) water delivery and (b) wastewater Charges
Wastewater charge is calculated at 159% of the water delivery charge

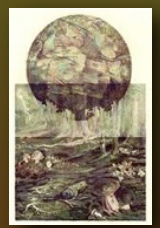
Typical New York City Charges
Assuming Proposed 9.4% Increase in FY2007 Rates

(Combined Water/Wastewater Charge)

	FY2006 Average	FY2007 Average	Change
Flat-Rate Customers			
Single Family Residential	$645	$705	$61
Two-Family Residential	$1,000	$1,094	$94
Walk-Up Apartments	$3,063	$3,351	$288
Charge per Dwelling Unit	$460	$504	$43
Elevator Apartments	$34,470	$37,710	$3,240
Charge per Dwelling Unit	$522	$571	$23
Metered Customers			
	Rates per 100 Cubic Feet		
Residential & Commercial			
Water	$1.65	$1.81	$0.16
Wastewater	$2.62	$2.87	$0.25
Combined	$4.27	$4.68	$0.40

100 cu. ft. = 748 gallons

Typical Metered Charges	Average Annnual Charges		
	FY2005	FY2006	Change
Single Family (100,000 gallons)	$571	$625	$53.70
Per Multifamily Unit (85,000 gallons)	$486	$531	$45.65



The Gaia Institute

The Metro Section B1
The New York Times WEDNESDAY, APRIL 11, 2007

New York City Water Rates Expected to Rise 11.5 Percent

By ANTHONY DePALMA

New York City officials plan to raise rates 11.5 percent on the water that every New Yorker uses, the largest annual increase in 15 years.

The proposed increase, set to go into effect in July if approved, as expected, by the New York City Water Board, would add $72 to the average water and sewer bill for a single-family home in the city. That would bring the average annual residential water bill to $699. Many apartments have water charges built into the rent, and co-ops and condos generally have them included as part of maintenance fees.

The double-digit increase comes several months after officials who run the water system said the city had more than $610 million in unpaid water bills. Uncollected bills have to be taken into account when new rates are calculated.

Officials attributed last year's 9.4 percent rate increase to higher costs for fuel, insurance and financing, as well as to "deadbeat homeowners" and others who do not pay their water bills.

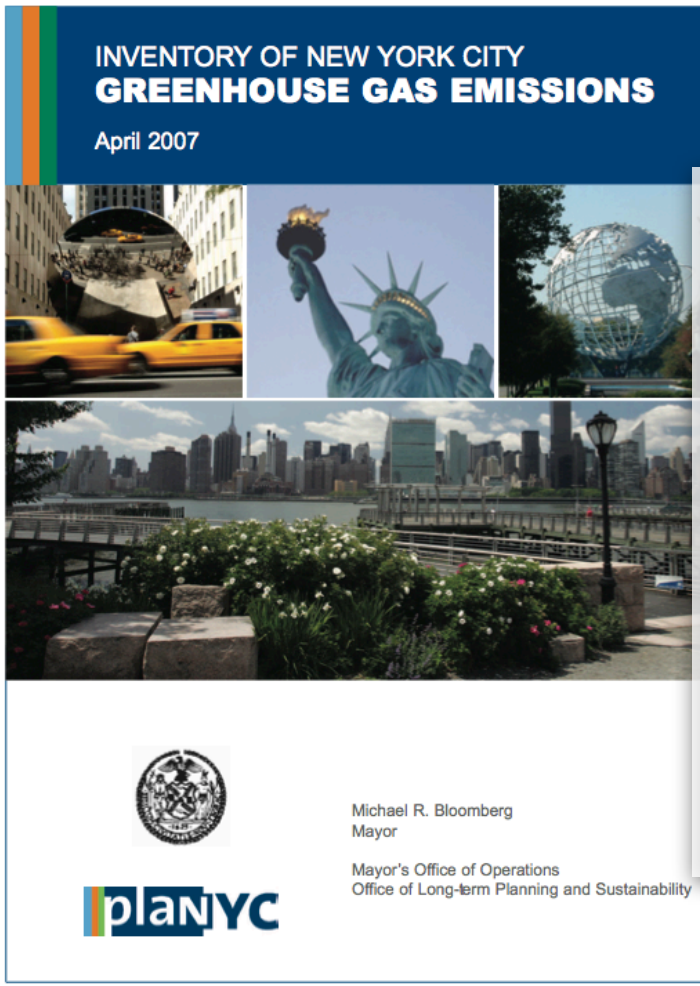
Although the number of water accounts in arrears remains high, officials said that the proposed rate increase, reported in The Daily News yesterday, had more to do with soaring costs for fuel, health care and supplies than with uncollected bills.

"We are working very hard to address that and hopefully, over time, improved collections will have a moderating effect on rate increases, but the needs of the system still dictate an increase of this magnitude," said Anne Canty, deputy commissioner of the city's Department of Environmental Protection, which runs the water system. "That's not to say that we are not pursuing outstanding accounts receivable. We are."

Ms. Canty said that overdue accounts had dropped to $580 million from $610 million, and that significant progress had been made in collecting long-overdue bills.

Continued on Page B8

Present stormwater infrastructure increases greenhouse gas emissions



VIII. Water and Sewer Sector

The facilities that make up the wastewater treatment and water and sewer systems that serve a municipality are often the buildings that use the greatest amount of energy; therefore, they are removed from the buildings sector for more specific examination. DEP-operated water pollution control plants, water supply, and wastewater transport systems, together with methane generated by the wastewater treatment process that escapes into the atmosphere, combined to produce 17 percent of emissions from City operations in 2006. It should be noted that New York City's water supply system is almost entirely gravity-fed. Therefore, the vast majority of energy consumed by this sector was used for wastewater transport and treatment. A total of approximately 655,000 metric tons of CO_2e were emitted by this sector in 2006.

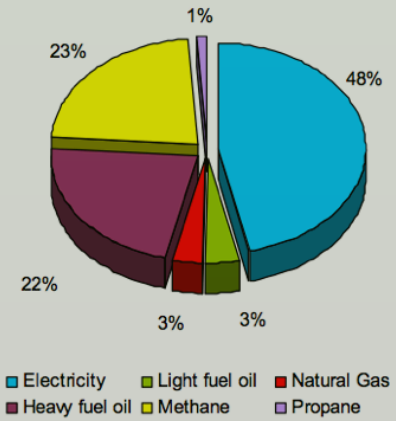
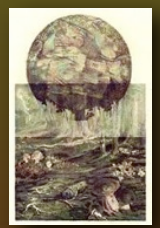


Figure 24. 2006 New York City government water and sewer CO_2e emissions by source (655,000 metric tons).



The Gaia Institute

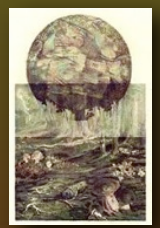
source: www.nyc.gov/2030

Stormwater as resource

It is not raining to me, It's raining daffodils;
In every dimpled drop I see Wild flowers on distant hills.
-Robert Loveman (April Rain, Harper's, May 1901)

Green roofs incorporate stormwater in plant structure:

- To capture carbon
- To treat water locally
- To cool the local environment
- Increase efficiency of PVs and HVAC equipment



The Gaia Institute

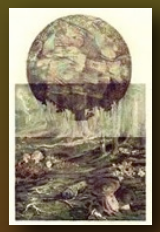
Stormwater capture potential

How much stormwater can be captured?

Plant coverage is major factor.

Can old field coverage levels, i.e. natural meadows and undisturbed fields, be achieved on green roofs?

To achieve this will require higher plant densities, i.e, increases in stem and foliage densities, or Leaf Area Index (LAI)



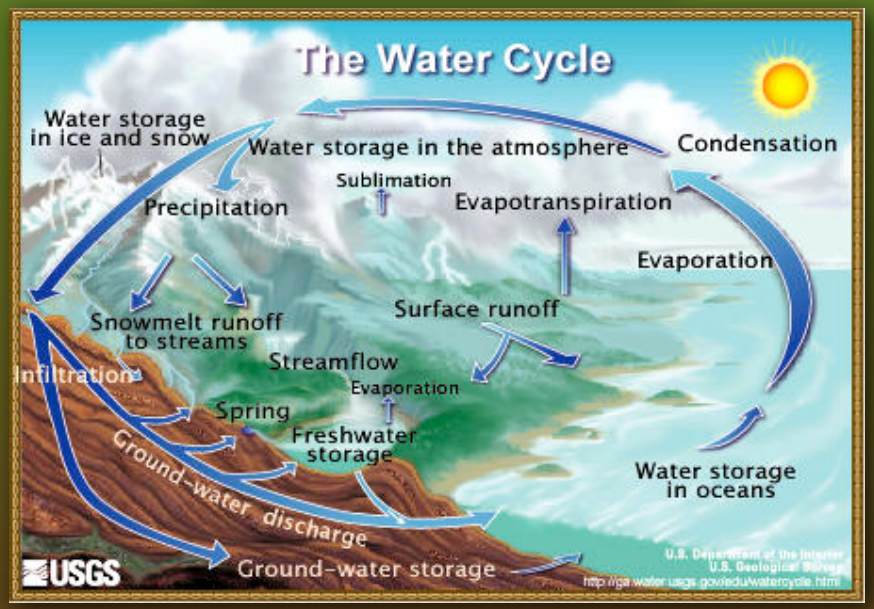
The Gaia Institute

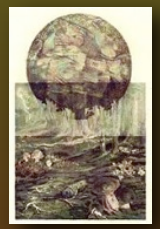
Evapotranspiration
Water=Power

Evapotranspiration: The process by which water vapor is discharged to the atmosphere as a result of evaporation from the soil and transpiration by plants.

Evapotranspiration of 6 mm of water over a one hectare field, the daily average in the temperate zone, the energy equivalent of 15 tons of dynamite

5.46 gallons of water equivalent to one ton of air conditioning





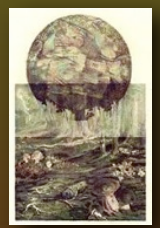
The Gaia Institute

Partitioning of Radiation and Temperature

The spines of the cactus at right reach temperatures higher than ambient, and re-radiate heat into the surroundings in proportion to the absolute temperature to the fourth power, T^4.

A more natural habitat (i.e. greater foliage density, or LAI) allows plants to more effectively partition energy.

Different leaves on the same plant serve different functions.

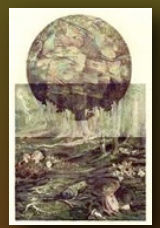


Water holding capacity of green roof

Goal is to optimize water-holding capacity of plant growth medium (and thereby reduce discharge to sewer)

During wet weather:
- capture stormwater in greater quantity

During dry weather:
- recycle greywater
- and re-use stormwater on green roof



The Gaia Institute

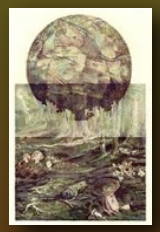
Nutrient delivery and availability

An additional consideration to support growth rates aiming to maximize coverage:

For annual biomass increase of 1 kg/sq. meter, require:

- 2-4%, or 20g to 40g N
- ≈1%, or 10g P

Because the growing media does not provide this level of nutrients, top dressing with compost is recommended

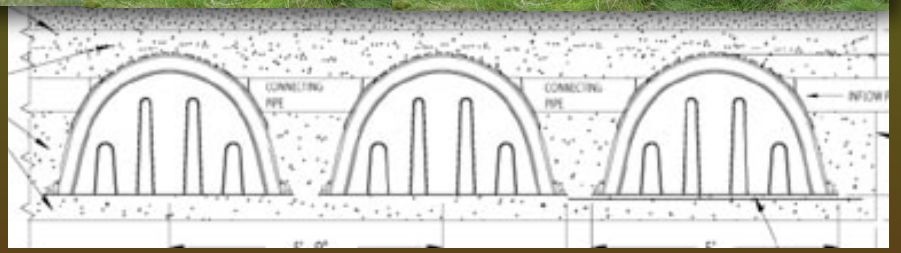


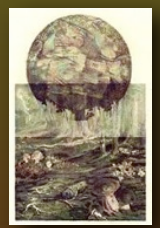
The Gaia Institute

A Commercial Facility in the Bronx

The Gaia Institute

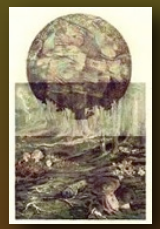
A Commercial Facility in the Bronx





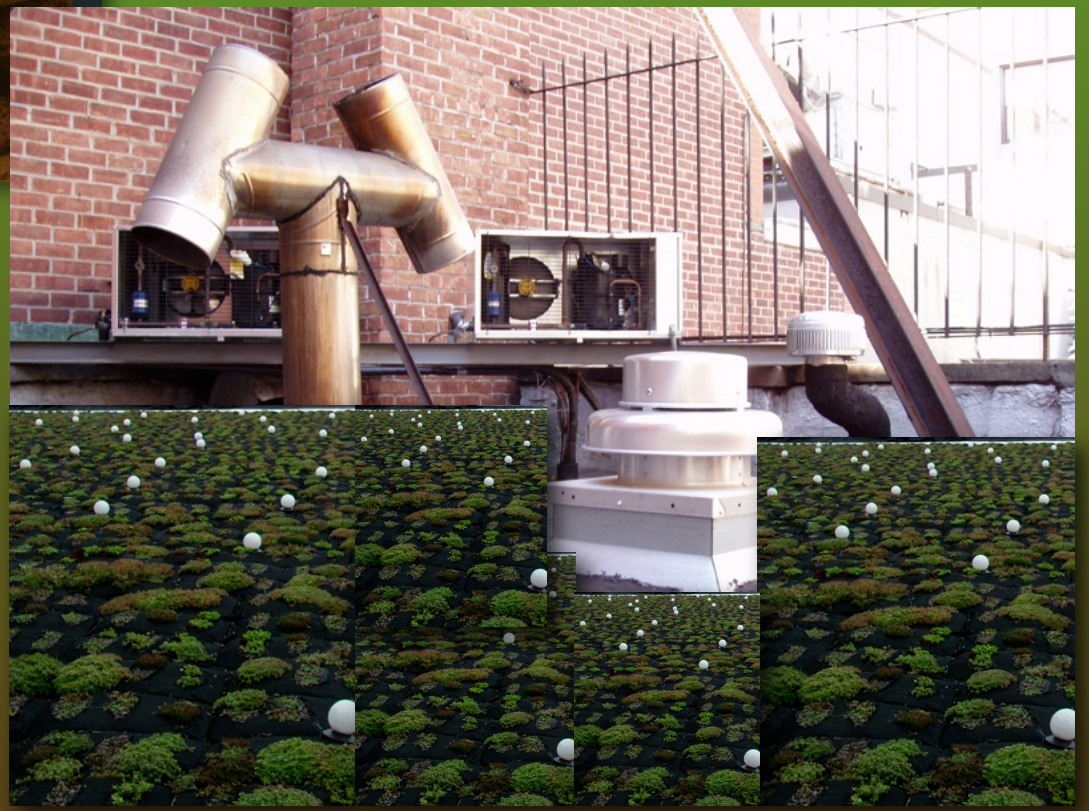
The Gaia Institute

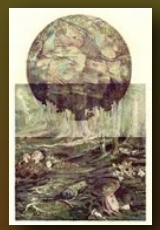
A Bakery in Manhattan



The Gaia Institute

A Bakery in Manhattan





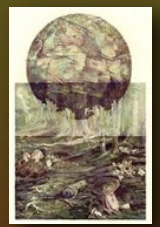
The Gaia Institute

Enhancing volume to capture runoff from a green roof

The Gaia Institute

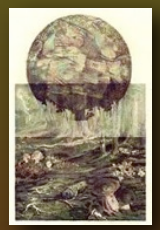
Volume Equivalent of 5 mm of Evaporation

Each five millimeters of evaporated water is the equivalent of a vertical column of atmosphere twenty feet tall, half the height of a four story building, or about two thirds the height of the trees in the above photo.



The Gaia Institute

Living Laboratory on the Horizon



The Gaia Institute

source: RVATR (Rafael Viñoly Architects Training & Research)