Sustainability Research at CUNY as it Relates to the Big Picture of New York Infrastructure

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ASCE Met Section Seminar:
Sustainable Infrastructure in Practice
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Part 1: Some big-picture (climate) considerations
Neither is well known, but both likely break the stability of recent decades.
Is our water supply secure?

- NYC's reservoirs hold about a year's worth of supply, 74% depleted in 1960s
- Aqueducts and tunnels are old and vulnerable to natural or human-caused disaster
Some possible solutions

- **Supply**: Tunnel No. 3; more pond/aquifer storage in city; diversify sources through rainwater collection, like Singapore

- **Demand**: water use reduced 30% in last 30 y despite population growth
NYC uses 13 GW natural gas and fuel oil for heating, cooking, etc. → $4 billion/year at current wholesale

Need research and policy developments to scale deep energy reduction approaches such as PassivHaus to retrofits of high-rise buildings
Flooding

• JFK airport under 2 m sea level rise – storm/tsunami surge or, in decades to centuries, ice melt
Can NYC be flood-proofed?

- “The potential 30-foot storm surge accompanying a Category 3 hurricane would flood large swaths of south Brooklyn, parts of Queens, Staten Island, and Manhattan below Canal Street ... floodwater might pour into the city's tunnels and subway system ... The city's wastewater treatment plants ... could back up, sending raw sewage into basements and bathrooms citywide.”

- A Dutch ASCE workshop idea is a barrier across the Verrazano Narrows – price tag: $6.5 billion

- Barriers are usually built *after* major floods

- Are there small steps for some resiliency in the short term?
A spectrum of adaptation responses

<table>
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<tr>
<th>Coastal adaptation (IPCC CZMS, 1990)</th>
<th>Adaptation objectives (Klein and Tol, 1997)</th>
<th>Adaptation responses (after Cooper et al., 2002; Defra, 2001)</th>
<th>Example</th>
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<tr>
<td>Protect</td>
<td>Increased robustness</td>
<td>Advance the line</td>
<td>Land claim; empoldering Estuary closure</td>
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<td>Hold the line</td>
<td>Dyke; beach nourishment</td>
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<td>Accommodate</td>
<td>Increased flexibility</td>
<td>‘Flood proof’ buildings</td>
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<td>Retreat</td>
<td>Enhanced adaptability</td>
<td>Retreat the line</td>
<td>Managed realignment</td>
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<td>Limited intervention</td>
<td>Ad hoc seawall</td>
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<td>Reversing maladaptive trends</td>
<td>Wetland restoration</td>
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<td>Sustainable adaptation</td>
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<td>Improved awareness and preparedness</td>
<td>Flood hazard mapping; flood warnings</td>
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<td>Community-focussed adaptation</td>
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“We’re going to have to do something,” [Stony Brook University oceanography professor Malcolm] Bowman said. “Or else you retreat, and that’s inconceivable. How are you going to retreat from New York City?”
Part 2: Some relevant projects at CCNY
Nitrogen Removal from Wastewater

The removal of nitrogen from wastewater is a focus of research at CCNY (Prof. Fillos, DEP contract)

\[
\text{N}_{\text{organic}} \xrightarrow{\text{NH}_3, \text{NO}_2^-, \text{NO}_3^-} \text{N}_2
\]

Why is it necessary to remove nitrogen from wastewater?
Environmental Consequences

• Nitrogen discharge into coastal waterbodies increases algae growth.
• The decomposition of organic matter (dead algae) creates hypoxic conditions on the ocean floor.

Nitrogen discharge has emerged as one of the greatest pollution problems in the coastal waters of the U.S.
Current NYC N removal bio-pathway

The quantities of alkaline chemicals, organic carbon, and aeration energy make nitrogen removal a very expensive process.
Unexplained nitrogen losses discovered at a WWTP in the Netherlands in 1990

Revealed to be an entirely new microorganism with a unique metabolic strategy
Anammox metabolism (ANSaerobic AMMonium OXidation)

NH$_4^+$ and NO$_2^-$ react directly to form N$_2$

A small fraction of NO$_2^-$ reacts to form NO$_3^-$, which allows biomass to form from inorganic carbon.

Stoichiometry:
$$1 \text{NH}_4^+ + 1.32 \text{NO}_2^- + 0.066 \text{HCO}_3^- + 0.13 \text{H}^+ \rightarrow 1.02 \text{N}_2 + 0.26 \text{NO}_3^- + 0.066 \text{CH}_2\text{O}_{0.5}\text{N}_{0.15} + 2.03 \text{H}_2\text{O}$$

Compared to current all-aerobic process:
- Only need to oxidize part of ammonium to nitrite, and then remaining nitrate
- Needs much less aeration
- Needs much less organic matter (methanol) addition
A Shortcut Through Conventional Denitrification

\[ \text{Accidental Carbon} \]

\[ \text{NO}_3^- \]

Ammonium Oxidation

\[ \text{O}_2 + \text{Alkalinity} \]

\[ \approx 50\% \text{ Conversion} \]

Nitrite Oxidation

\[ \text{Denitrification} \]

\[ \text{Organic Carbon} \]

\[ \text{Anammox} \]

\[ \text{N}_2 \]
Anammox at CCNY

- At CCNY, nitrogen removal is achieved in multiple laboratory scale anammox reactors since January 2008.
- The past three years of research focused on the physiology and growth kinetics of anammox biomass grown in a real New York City waste stream.
Anammox Pilot Demonstration

One of the anammox process configurations evaluated at CCNY is currently being scaled up to an 1100 gallon demonstration reactor at the 26th Ward WPCP (Brooklyn).
CR3MUS
CENTER FOR RECLAMATION REUSE AND RECYCLING OF MATERIALS FOR URBAN SUSTAINABILITY

A Multidisciplinary Research Center at CCNY exploring the tangible and intangible benefits of Reclamation, Reuse and Recycling of natural and manmade materials in sustainable urban environments.
PI: Prof. Vasil Diyamandoglu
Industrial and commercial solid waste reuse.
Effects of single and multi-cycle reuse on material properties.
Short and long term life/service implications.
Modeling of time dependent material deterioration.
Reliability of reusable materials.
Certification procedures of reused material properties.
Electronic wastes – recovery, reuse and disposal issues
Construction and demolition wastes
Economic analysis of implementation of materials reuse
Environmental impact assessment of materials reuse and recycling
Societal impact of materials reuse.
CR3MUS

Programs Funded by the New York City Department of Sanitation
Bureau of Waste Prevention Reuse and Recycling

NYC Materials Exchange Development Program
Strengthening NYC’s materials exchange and reuse sector

www.nycmedp.org

MEDP helps New York City businesses save money and improve the Environment by diverting “reusables” from the solid waste stream

www.wastematch.org

NYC's free commercial on-line materials exchange program
Research and Development - 
Commercial solid waste in NYC is 4-5 times as large as household waste, yet mostly goes unnoticed. Develop methodologies to track and reduce this solid waste source.

Donation Referrals through NYC WasteMatch - 
NYC WasteMatch is the only public on-line materials exchange and reuse service, free to the entire NYC commercial sector.

Educational Opportunities - 
Materials Exchange and Reuse Certificate Program. Consists of eight 3-hour seminars held at CCNY and at facilities around NYC.

Technical Assistance and Workshops

Annual Materials Reuse Conference
Held at CCNY in mid-November of each year. 2011 will be the fourth conference.
MEDP Member Reuse organizations in NYC (over 100)

Computers
- Computers for Youth
- Lower East Side Ecology Center
- Non-Profit Computing
- Per Scholas

Furniture
- Furnish a Future
- Green Office Systems
- Tools for Schools

Clothing
- Goodwill Industries of Greater NY and NJ
- Bottomless Closet (NYC)
- NYC Clothing Bank

Building Materials
- Build it Green
- Demolition Depot
- Rebuilding Source
Used and surplus materials handled by NYC WasteMatch include:

- Building Materials
- Computers, Electronics, Office Equipment
- Containers & Packaging
- Furniture
- Medical Equipment & Supplies
- Metals, Glass, Plastics
- Office Supplies & Art Supplies
- Paper & Cardboard
- Surplus Food
- Textiles, Fabric & Leather

Since April 1998, NYC Waste Match Activities Produced:

- Number of Transactions / Exchanges: 4035
- Tons of Waste Diverted: 1,123,413
- Total Cost Savings: $5,189,037
Sustainable Materials Research at CCNY

Green Building Materials

Chemical Sensing
Carbon Sequestering Infrastructure Materials

CO$_2$

Solid Waste (Ca$^{2+}$)
- Slag
- Fly ash
- Recycled glass

Carbonation Chamber
CaO + CO$_2$ $\Rightarrow$ CaCO$_3$

Carbonate Concrete
- Pavers
- Roadways

Concrete made from CO2 and Solid Waste

Weihua Jin, CCNY; Collaborator: Masoud Ghandehari, NYU-Poly
Green Concrete for the CCNY Concrete Canoe

Glascrete from Recycled Glass

Weihua Jin, CCNY; Collaborator: Christian Meyer, Columbia University
Green Concrete for Buildings and Architecture

Weihua Jin, CCNY; Collaborator: Baogui Zhang
Chemical Sensing for Healthy Infrastructure

Weihua Jin, CCNY; Collaborator: Masoud Ghandehari, NYU-Poly