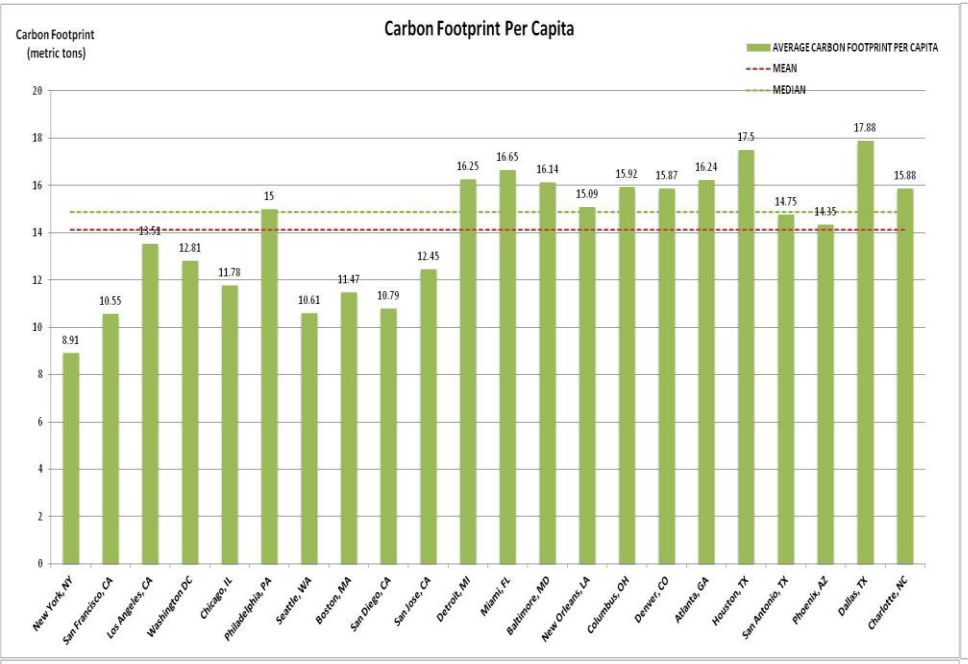
Energy-Water-Climate Change Nexus
– a Case of New York City

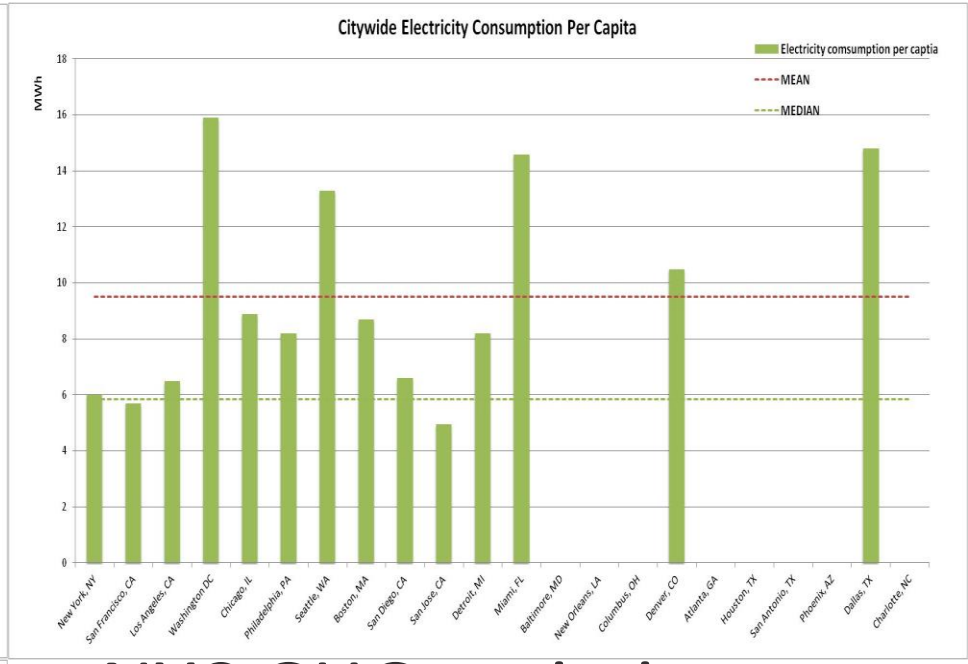
NYIT NSF Workshop - URBAN INFRASTRUCTURES

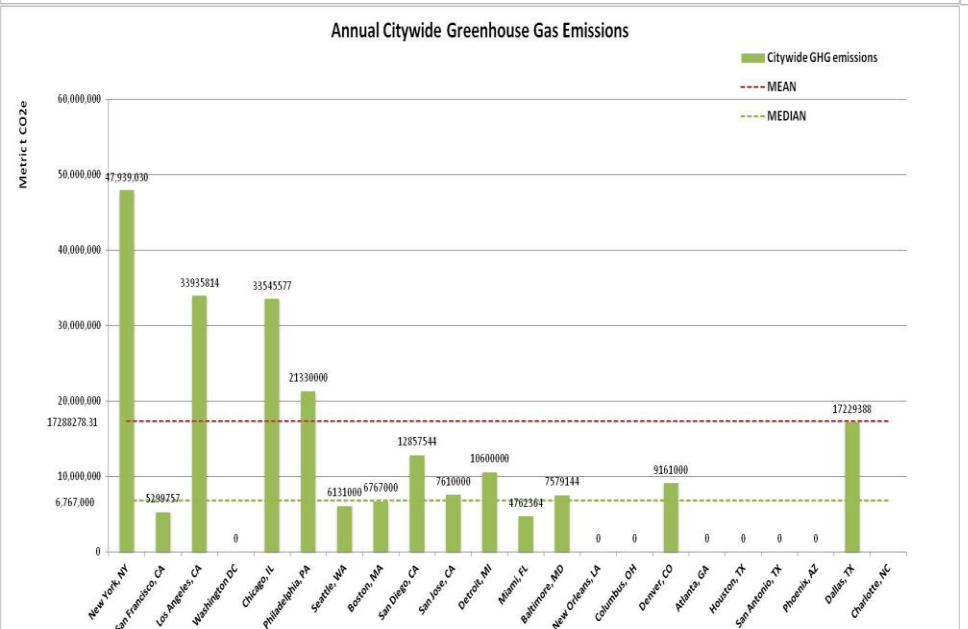
December 8, 2016

Vatsal Bhatt

The comparison of New York City with other cities with a set of indicators





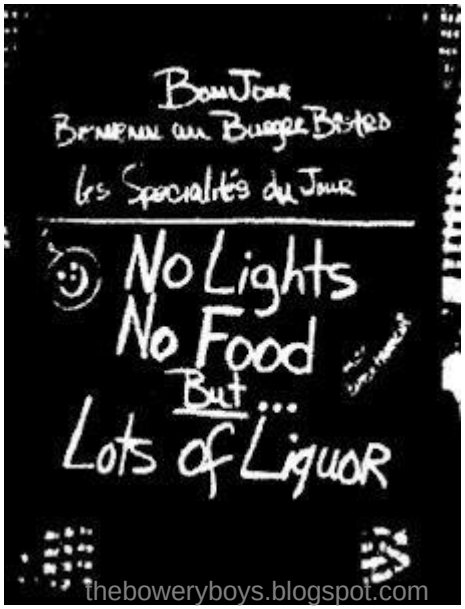


- NYC GHG emissions are the highest among cities in U.S.
- Buildings consume 78% of energy in NYC

New York City Blackout 2003

50 Million Lose Power

Economic Losses: $7-10 billion



USEPA asked us for help

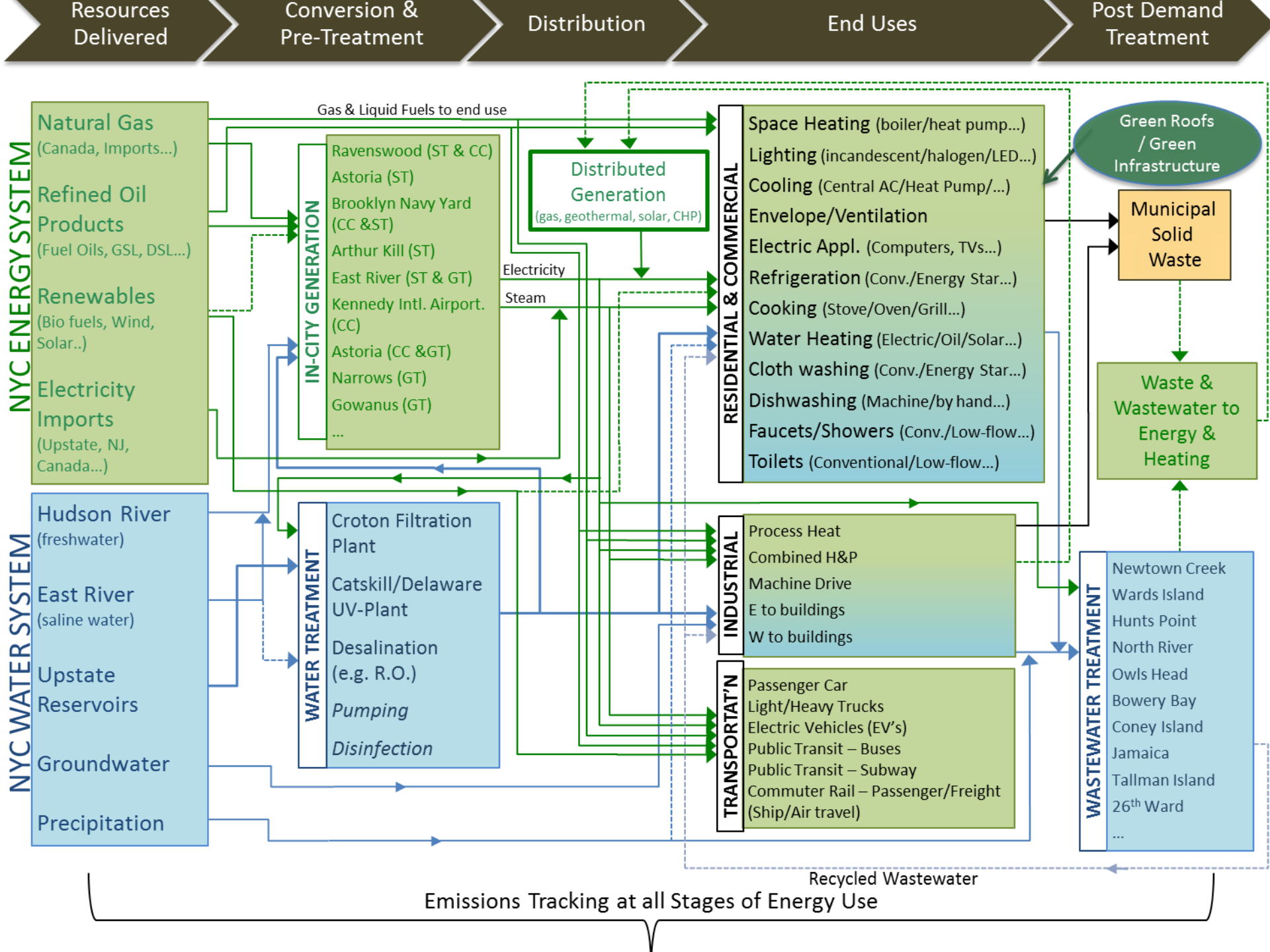
nasa.gov/topics/earth/features/ny-roofs.html

We Used Integrated Analysis Methods to Provide Simple Solutions

- U.S. MARKAL model for comprehensive Energy-Water analysis
- Reduce PEAK Electricity Demand (cool the city)
- Provide Green Roofs and White Surfaces
- Increase Energy Efficiency

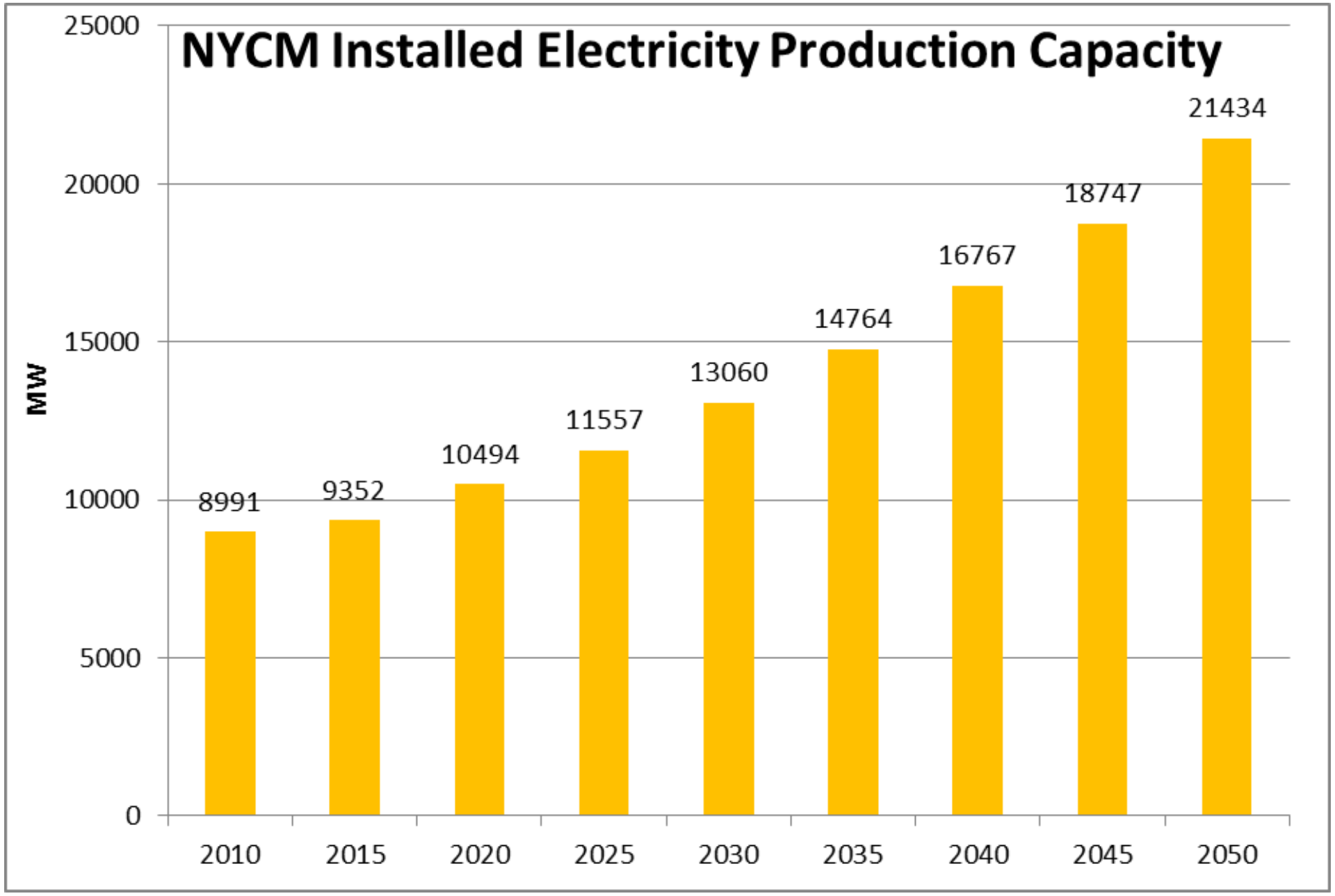
BNL's Energy Policy/Technology Analysis

- Core focus on long-term integrated energy, environmental and economic analysis using the MARKAL family of models
  - MARKAL was developed at BNL in collaboration with International Energy Agency
  - Currently working with many MARKAL variants (e.g. 10-region U.S. Model, Single region U.S. Model, 15-region ETP Global Model, New York City Model, Multi-region Long Island Model)
- Relevant Agencies and Projects for Energy and Climate Change Economics Modeling
  - U.S. Department of Energy
  - U.S. Environmental Protection Agency
  - Harvard "Transforming U.S. Energy Innovation"
  - Hong Kong MARKAL model
  - Taiwan MARKAL model
  - South Korean MARKAL model

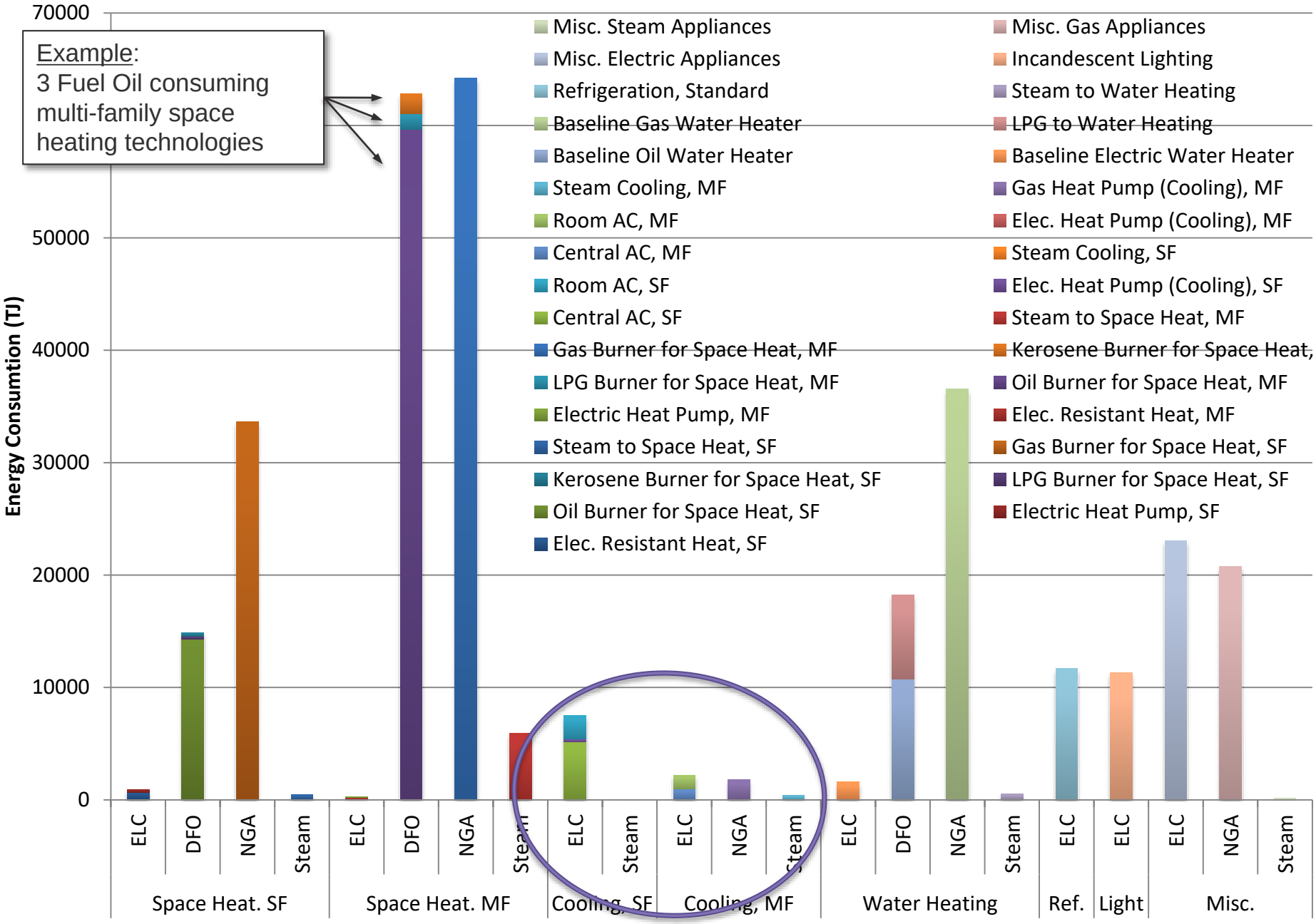

Resources Delivered
Conversion & Pre-Treatment
Distribution
End Uses
Post Demand Treatment
NYC ENERGY SYSTEM
Natural Gas
(Canada, Imports...)
Refined Oil Products
(Fuel Oils, GSL, DSL...)
Renewables
(Bio fuels, Wind, Solar..)
Electricity Imports
(Upstate, NJ, Canada...)
Gas & Liquid Fuels to end use
IN-CITY GENERATION
Ravenswood (ST & CC)
Astoria (ST)
Brooklyn Navy Yard (CC &ST)
Arthur Kill (ST)
East River (ST & GT)
Kennedy Intl. Airport. (CC)
Astoria (CC &GT)
Narrows (GT)
Gowanus (GT)
...
Distributed Generation
(gas, geothermal, solar, CHP)
Electricity
Steam
RESIDENTIAL & COMMERCIAL
Space Heating (boiler/heat pump...)
Lighting (incandescent/halogen/LED...)
Cooling (Central AC/Heat Pump/...)
Envelope/Ventilation
Electric Appl. (Computers, TVs...)
Refrigeration (Conv./Energy Star...)
Cooking (Stove/Oven/Grill...)
Water Heating (Electric/Oil/Solar...)
Cloth washing (Conv./Energy Star...)
Dishwashing (Machine/by hand...)
Faucets/Showers (Conv./Low-flow...)
Toilets (Conventional/Low-flow...)
Green Roofs / Green Infrastructure
Municipal Solid Waste
Waste & Wastewater to Energy & Heating
NYC WATER SYSTEM
Hudson River
(freshwater)
East River
(saline water)
Upstate Reservoirs
Groundwater
Precipitation
WATER TREATMENT
Croton Filtration Plant
Catskill/Delaware UV-Plant
Desalination (e.g. R.O.)
Pumping
Disinfection
INDUSTRIAL
Process Heat
Combined H&P
Machine Drive
E to buildings
W to buildings
TRANSPORTAT'N
Passenger Car
Light/Heavy Trucks
Electric Vehicles (EV's)
Public Transit – Buses
Public Transit – Subway
Commuter Rail – Passenger/Freight
(Ship/Air travel)
WASTEWATER TREATMENT
Newtown Creek
Wards Island
Hunts Point
North River
Owls Head
Bowery Bay
Coney Island
Jamaica
Tallman Island
26th Ward
...
Recycled Wastewater
Emissions Tracking at all Stages of Energy Use

Considerations for the Base Case

- Productive life of existing power plants are extended to 2050 (in expectation of retrofits/new technology at the same location).
- Land-use laws, expensive real estate and mandatory requirements of the Federal Energy Regulatory Commission for producing 80% of needed electricity demands within geographical boundary of the City are expected to drive that behavior.
- Due to NYC sustainability goals, new generation capacity will be added by very clean and increasingly efficient combined cycle gas turbines in the business-as-usual.
- Cleaner options like nuclear and super-efficient integrated coal gasification combined cycle with carbon capture and sequestration are not considered due to obvious challenges recently faced by these options in NYC.


NYCM Installed Electricity Production Capacity
MW
25000
20000
15000
10000
5000
0
8991
9352
10494
11557
13060
14764
16767
18747
21434
2010
2015
2020
2025
2030
2035
2040
2045
2050

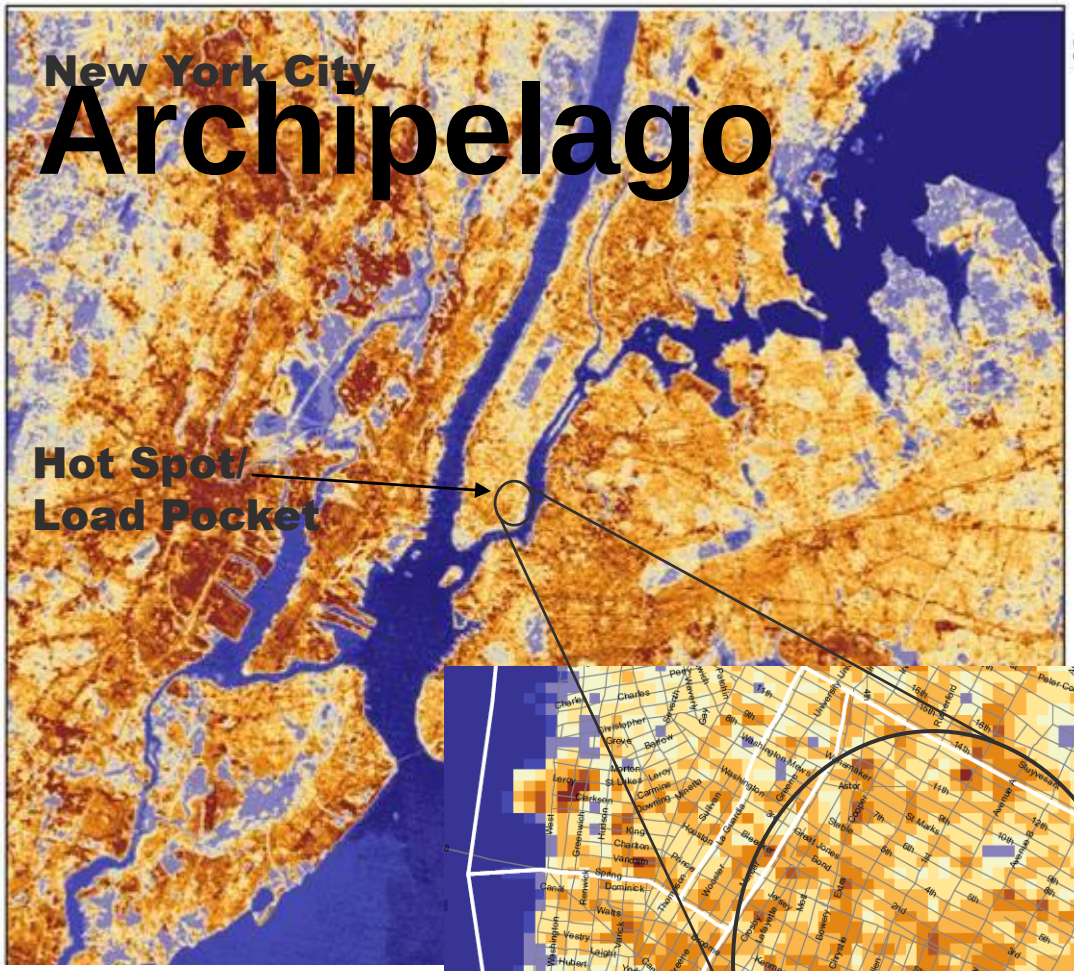
End Use Technologies: Residential Sector



Rationale and Outline

- Buildings are the biggest energy consumers in NYC (78%)
- Utilize New York City MARKAL for quantifying the impact of energy efficiency and load management options
- Capture the synergies and offsets of deploying energy efficient technologies in buildings
- Results of this work serve as a guideline in implementing urban energy efficiency and other forms of urban environmental improvement through cost-effective planning at the institutional and local level in other cities (especially emerging economies)
- Demands are increasing but there is not enough supply

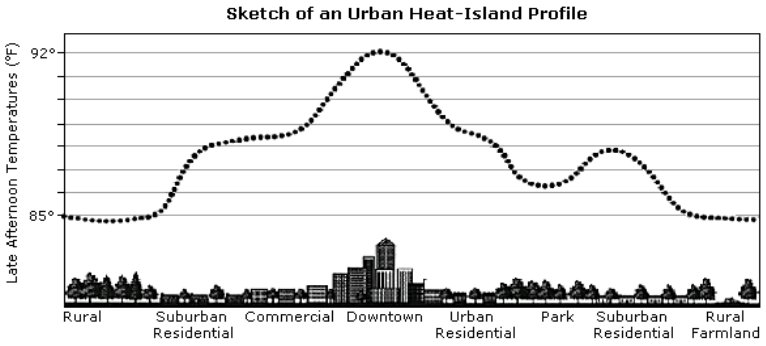
Heat Archipelago



SURFACE TEMPERATURE
Landsat ETM
July 22 2002
10:30 AM

Legend

20.56 - 27.63
27.64 - 28.61
28.62 - 31.50
31.51 - 35.26
35.27 - 38.01
38.02 - 39.82
39.83 - 41.60
41.61 - 43.36
43.37 - 45.10
45.11 - 63.01



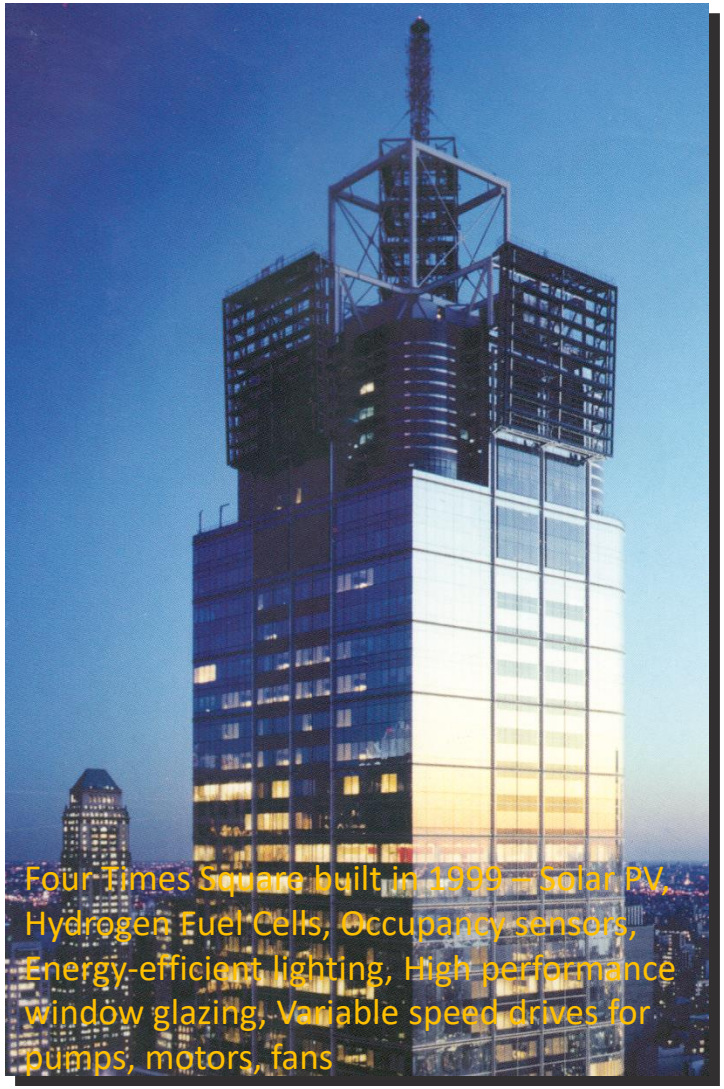
Maps Source: NYSERDA UHI Study

That ain’t simple…

- Complex Steam-heating
- Repowering power plants
- 80% generation has to come from within city – mandated by Federal Energy Regulatory Commission

Strategies: Green Roof, Urban Reforestation and White Surfaces

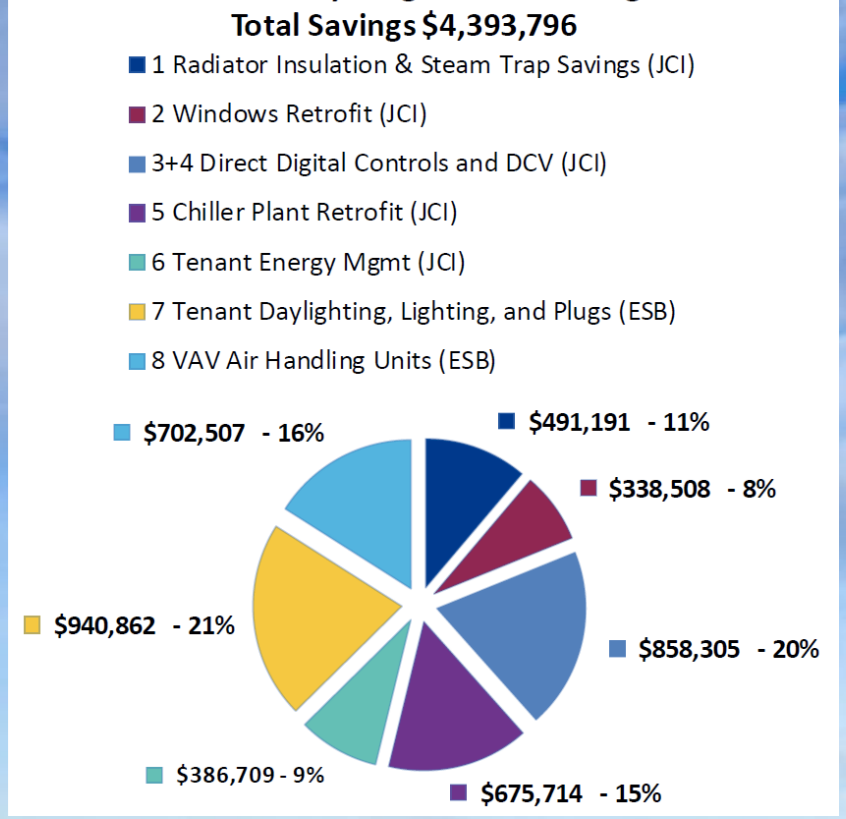
Energy Efficient Green Buildings

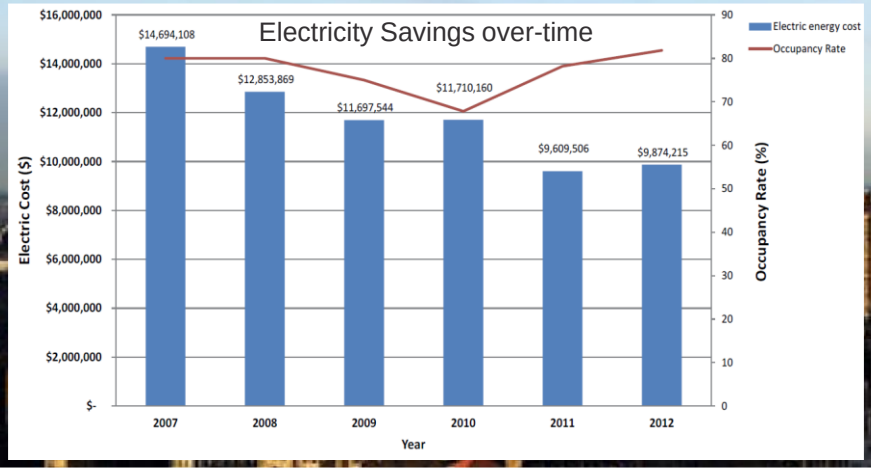


Four Times Square built in 1999 – Solar PV, Hydrogen Fuel Cells, Occupancy sensors, Energy-efficient lighting, High performance window glazing, Variable speed drives for pumps, motors, fans

Bank of America – LEED Platinum Building with MicroCHP & ICE Storage for cooling

Energy Efficiency Retrofits – Empire State Building





Reduce Loads

↓

Use Efficient Technologies

↓

Provide Controls

- 38% Energy Savings

esbnyc.com

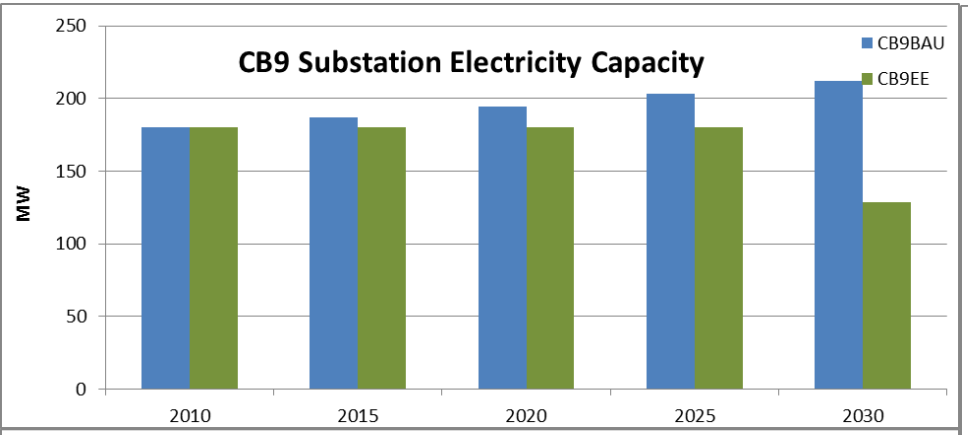
Jones Lang LaSalle — Real value in a changing world

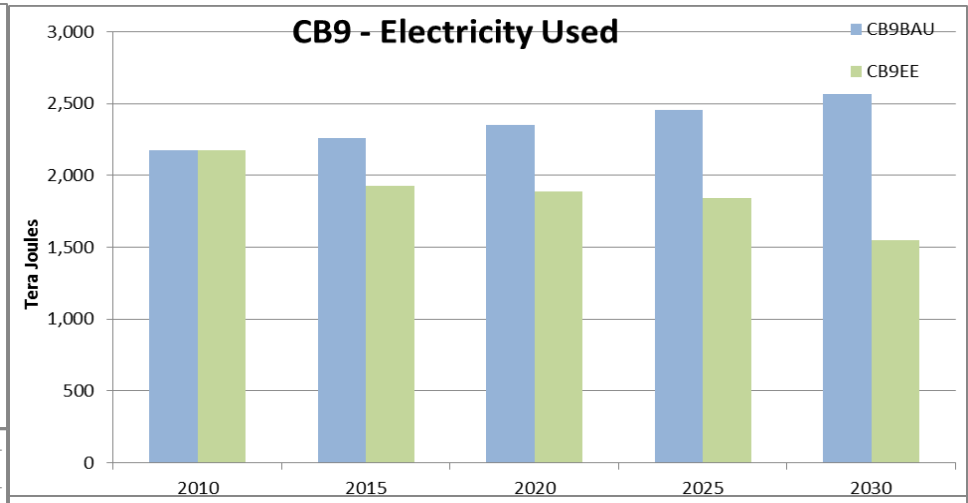
Clinton Foundation | Clinton Climate Initiative

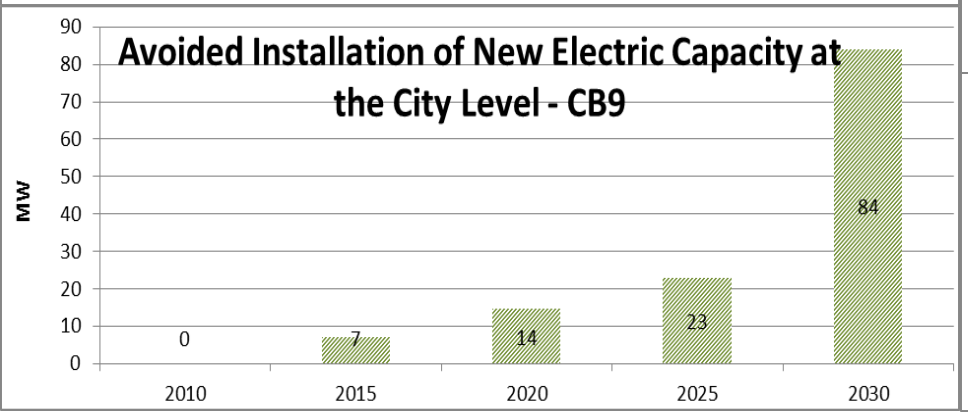
Rocky Mountain Institute

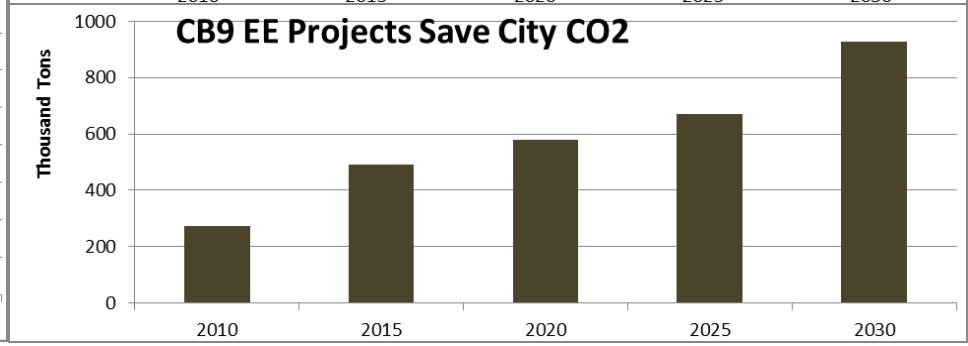
Johnson Controls

Buildings Energy Efficiency





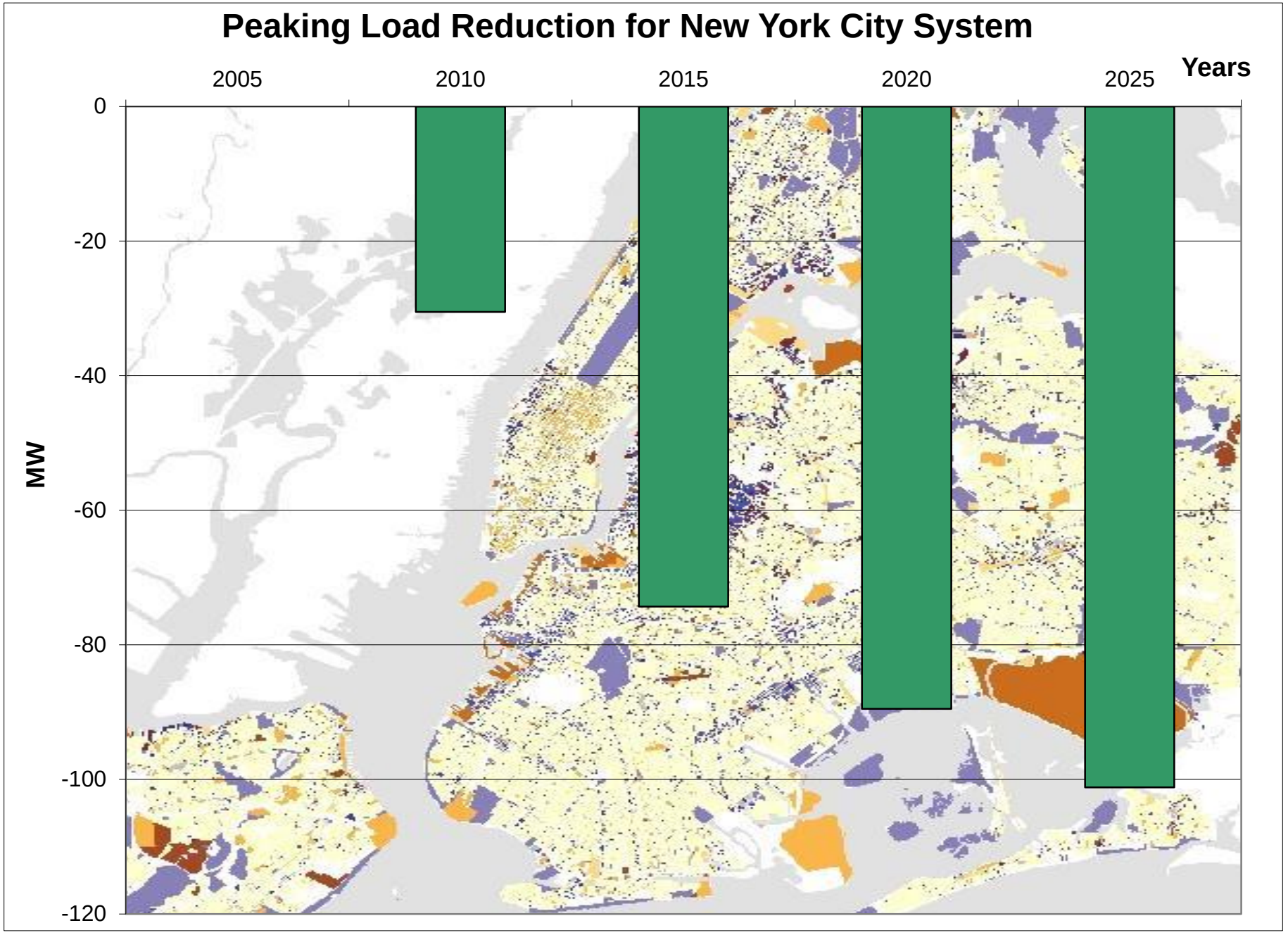


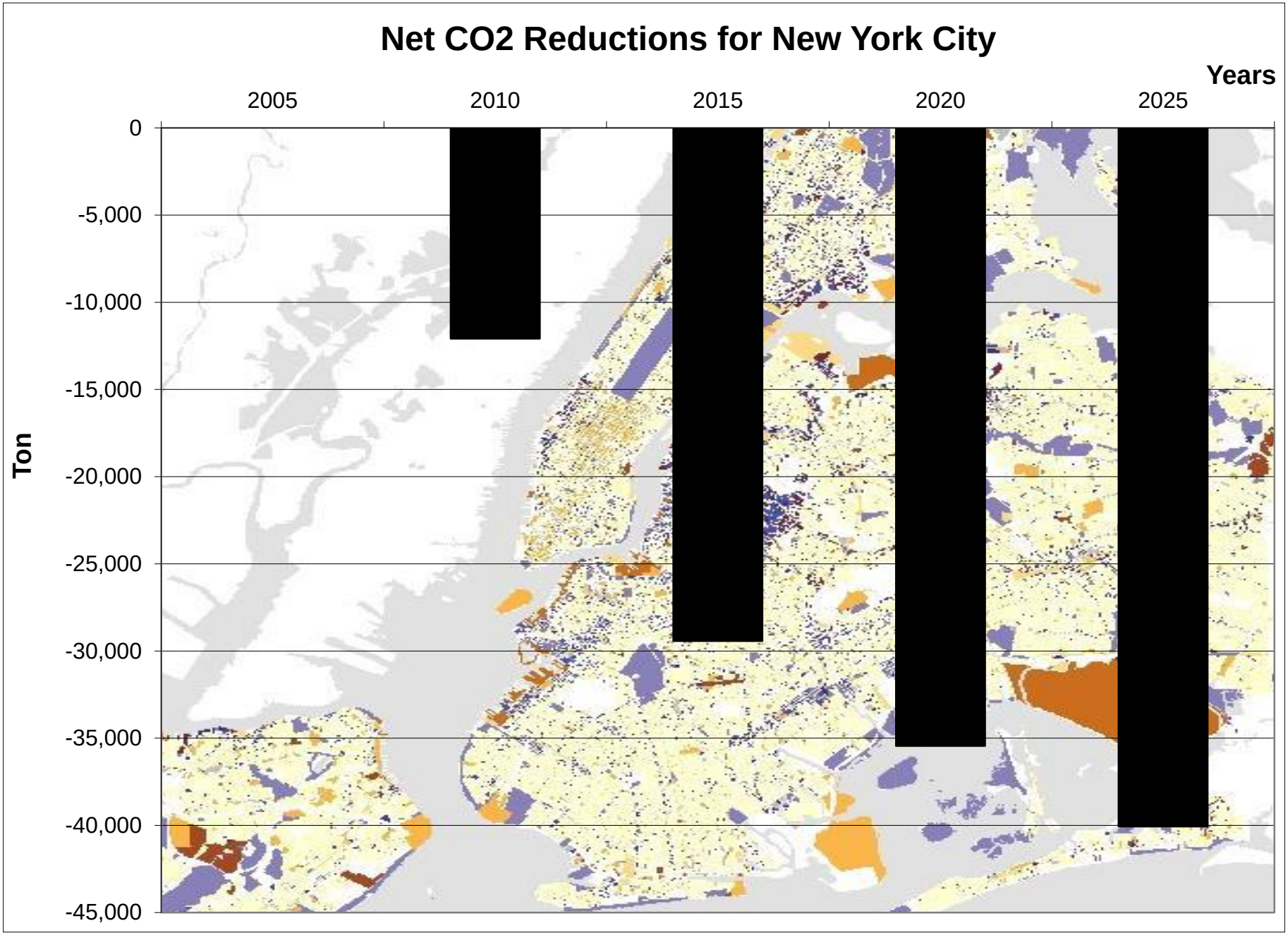


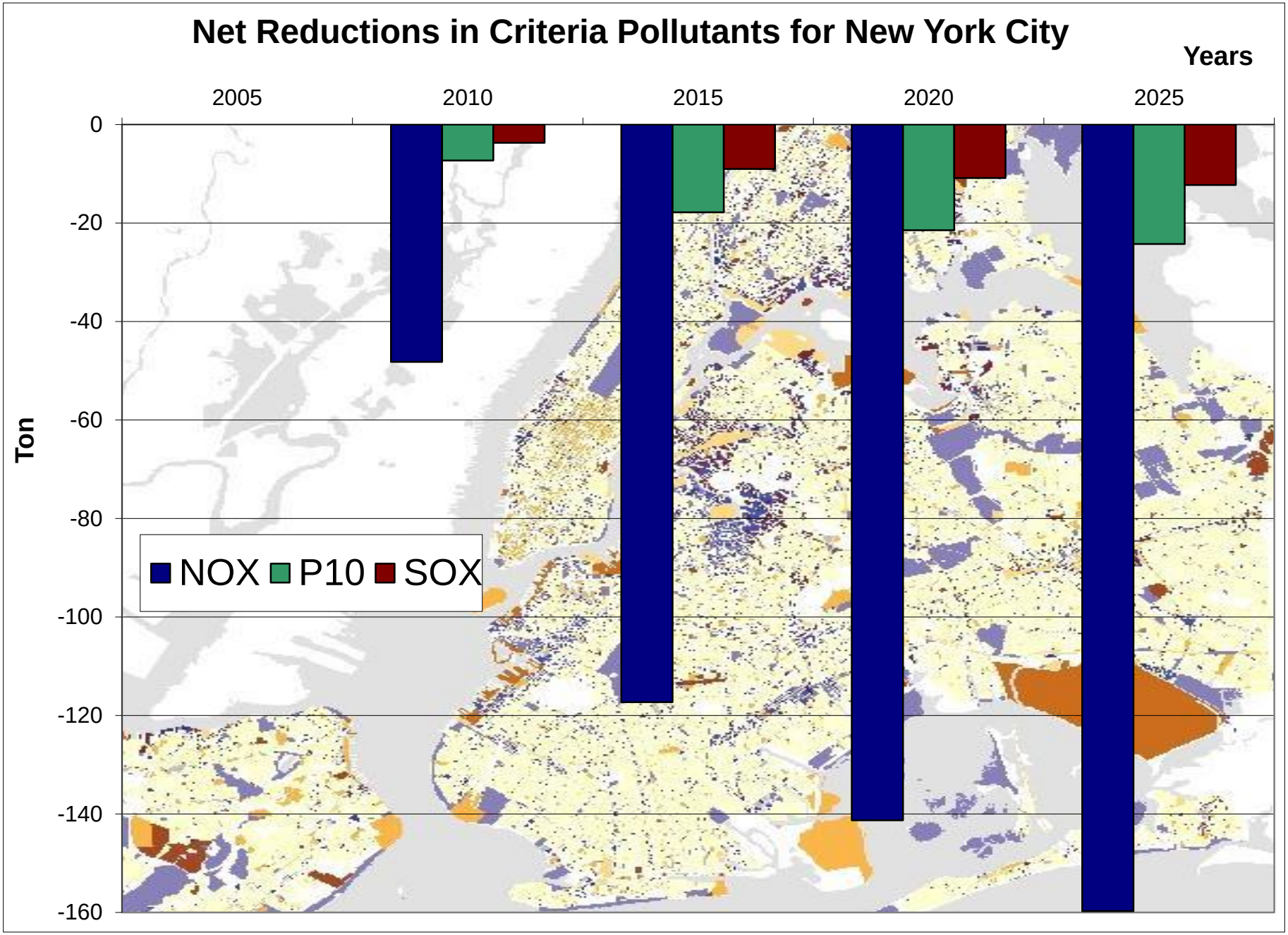
- Piloting EE&C strategies at a neighborhood level shows targeted benefits
- Proven successful, they can be upscaled to the City

Combined Savings add-up

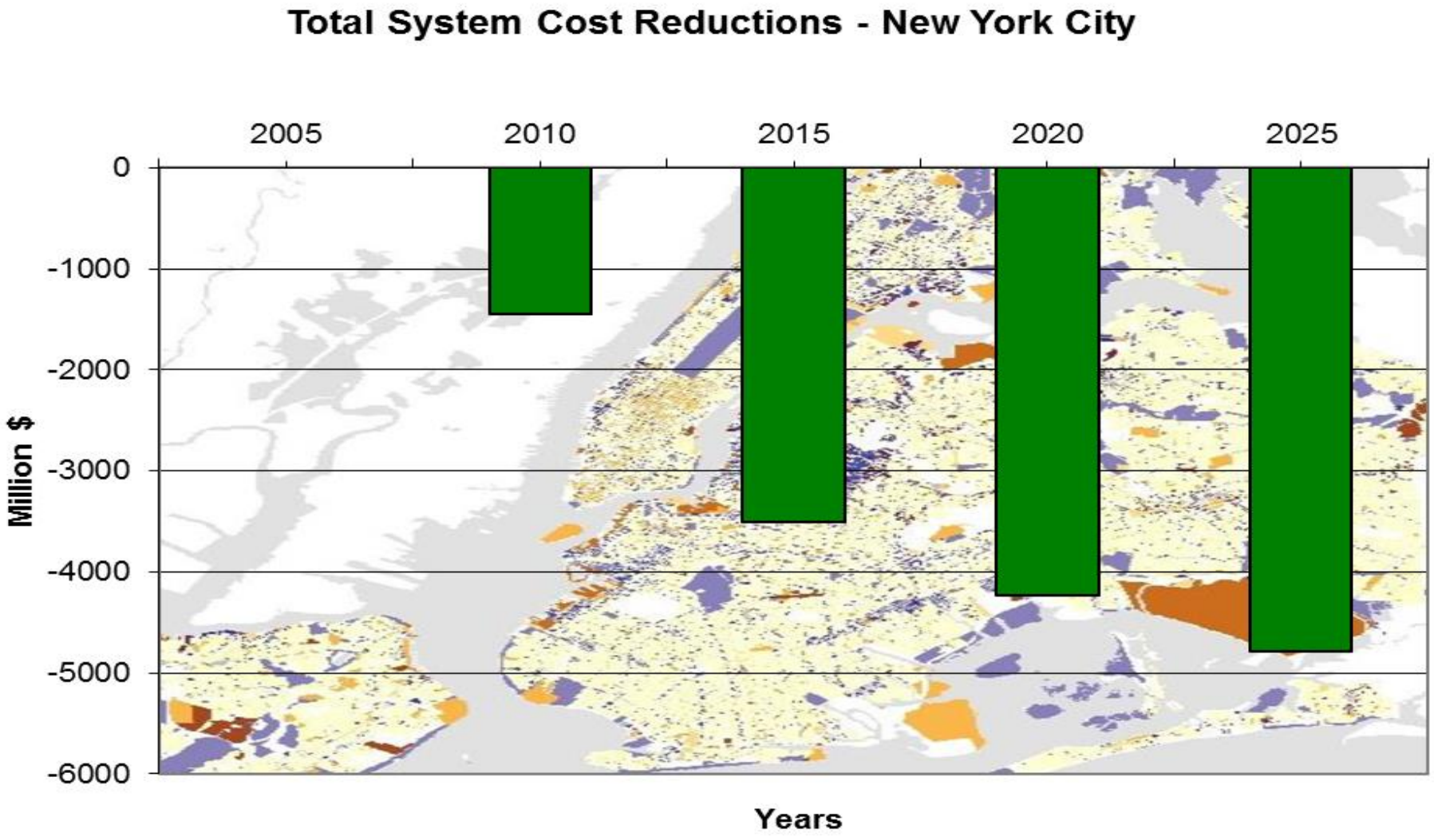
- Lower Manhattan demand reduction for commercial 30-40% & for residential 20% by 2025
- Peak-load reduction for Lower Manhattan 23% and for New York City 6% by 2025


Peaking Load Reduction for New York City System
Years
2005
2010
2015
2020
2025
0
-20
-40
-60
-80
-100
-120
MW


Net CO2 Reductions for New York City
Years
2005
2010
2015
2020
2025
Ton
0
-5,000
-10,000
-15,000
-20,000
-25,000
-30,000
-35,000
-40,000
-45,000


Net Reductions in Criteria Pollutants for New York City
Years
2005
2010
2015
2020
2025
Ton
0
-20
-40
-60
-80
-100
-120
-140
-160
NOX
P10
SOX

By the way, it Saves Money as Well!



NYC Water System

- 1.3 billion gallons per day supplied
- 19 reservoirs
- 3 aqueducts
- 3 tunnels in the city
- 6000 miles of distribution mains

West Branch of the Delaware River

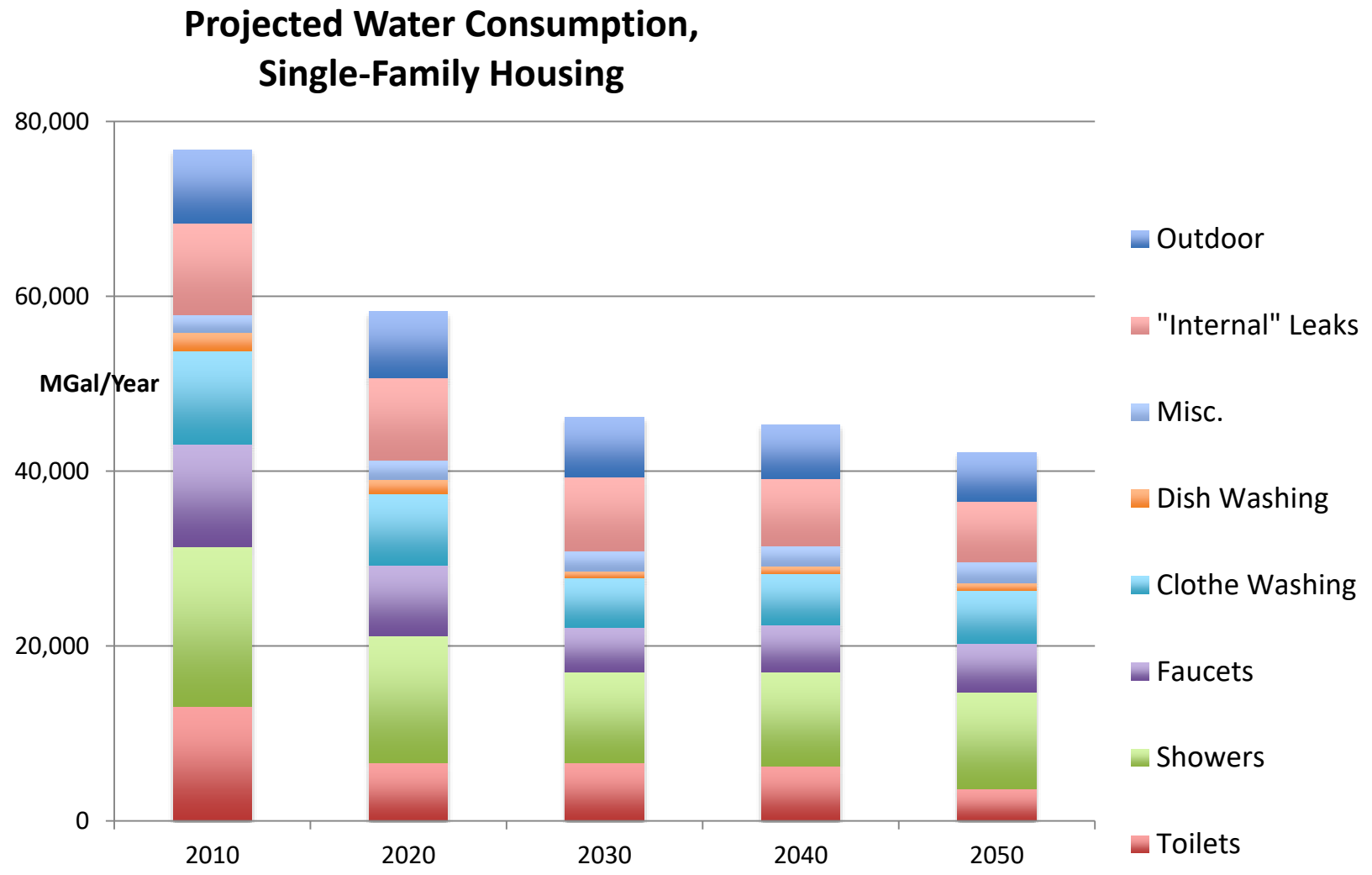
Credit: NYC Department of Environmental Protection

Water flowing over the Cannonsville Reservoir Spillway

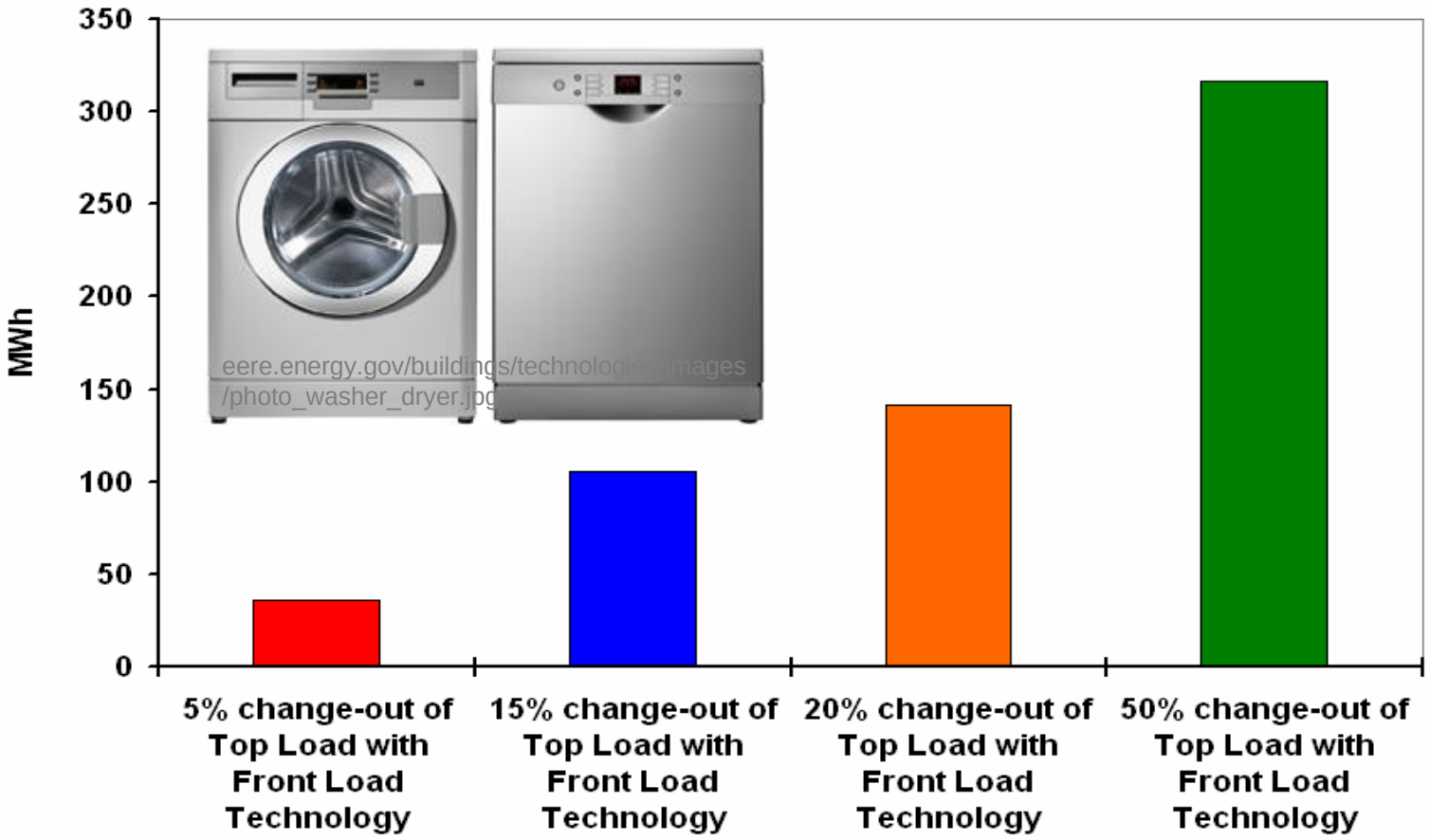
City Water Tunnel No.3

Credit: NYC Department of Environmental Protection

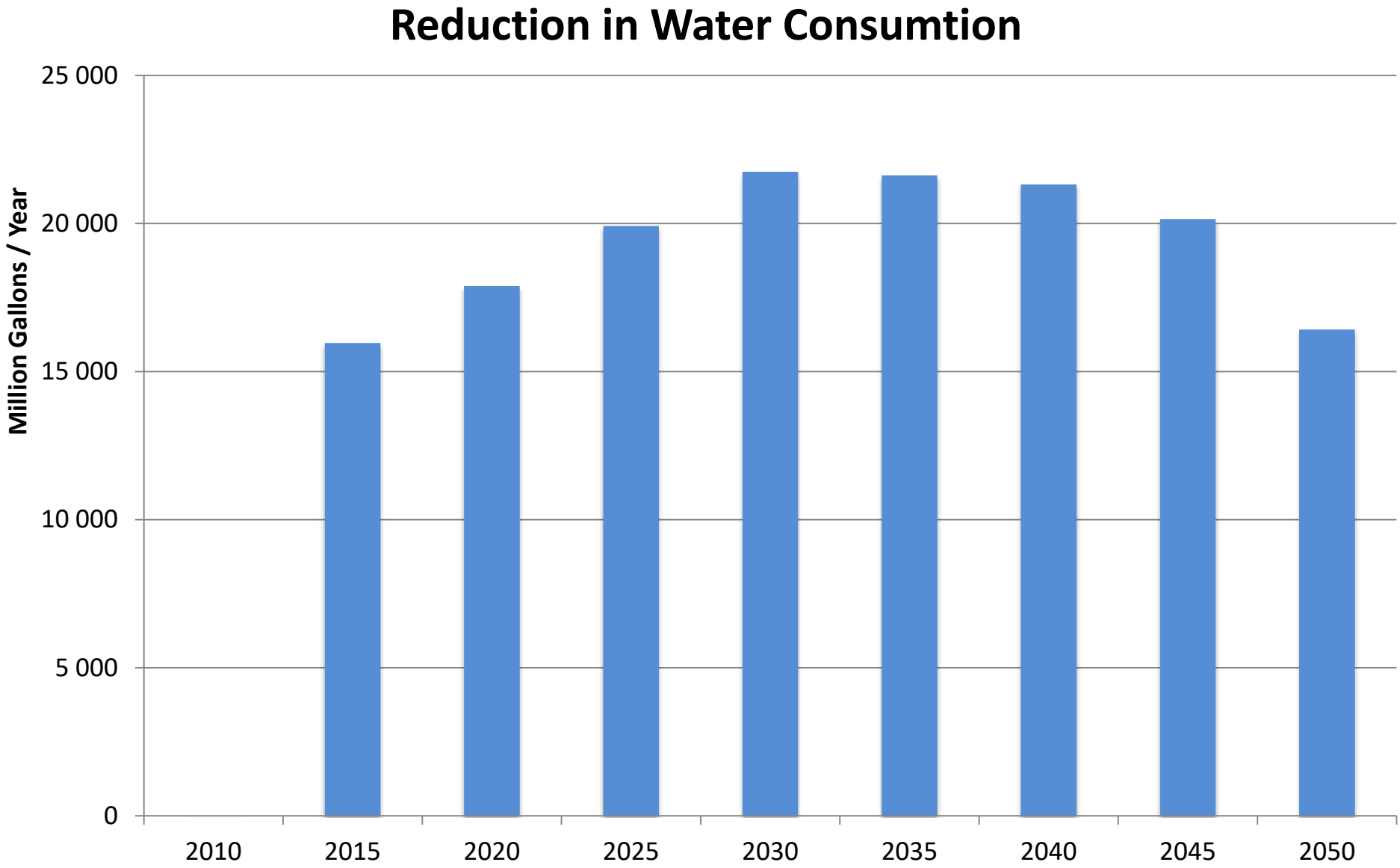
Reduce Quantity of Water Treated



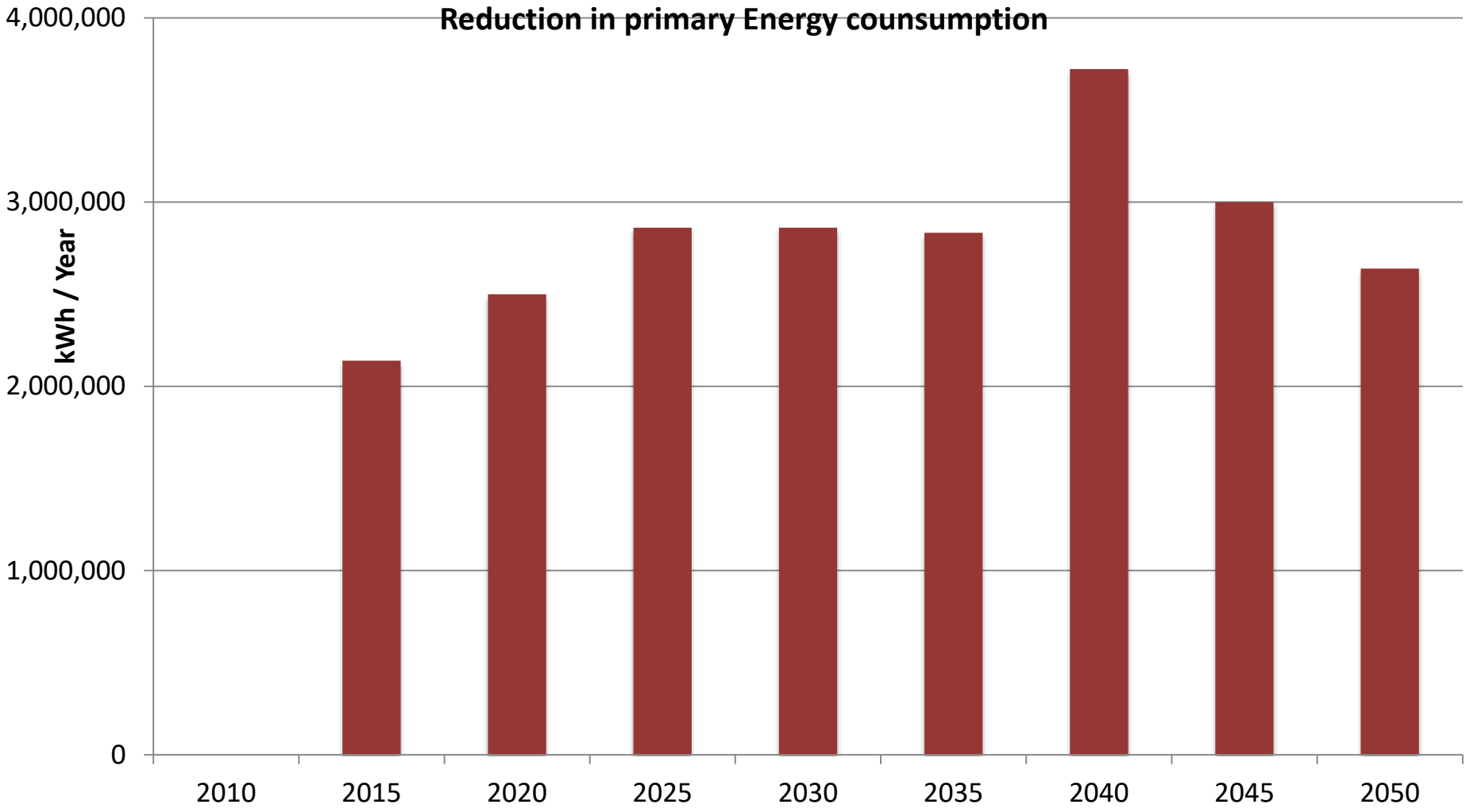
Simple Change in Water-efficient Appliances: Save Big Energy and Water



More Water Efficiency – More Energy Savings

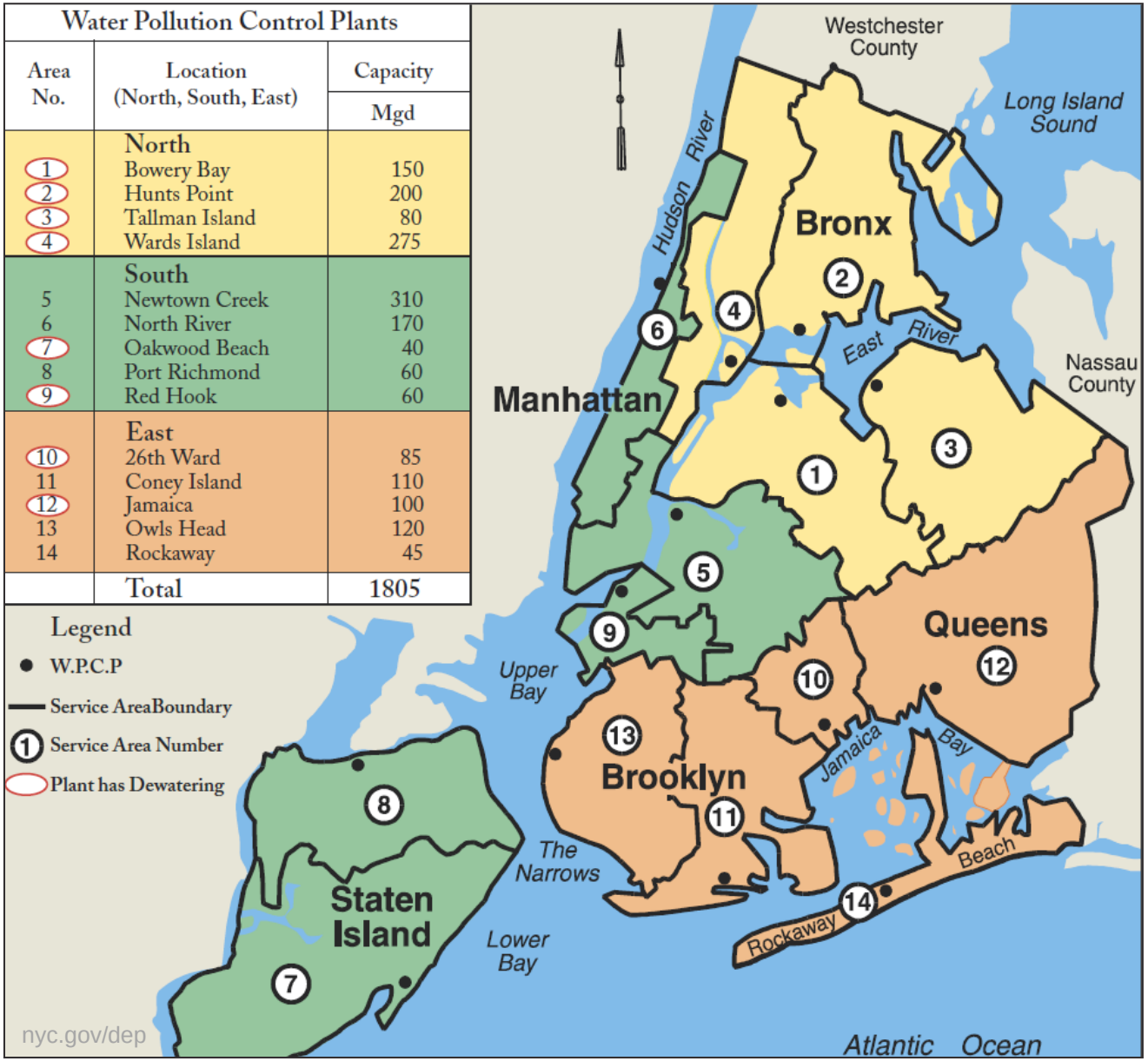


More Water Efficiency – More Energy Savings



NYC Waste Water Treatment Plants

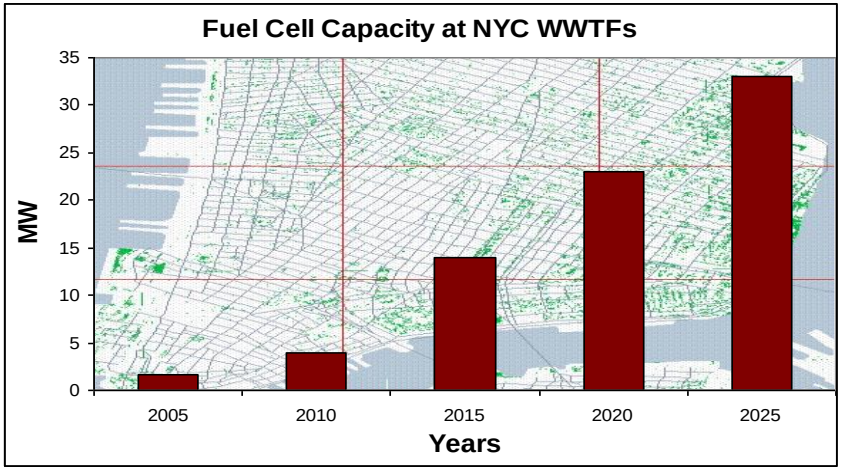
Water Pollution Control Plants		
Area No.	Location (North, South, East)	Capacity Mgd
	North	
1	Bowery Bay	150
2	Hunts Point	200
3	Tallman Island	80
4	Wards Island	275
	South	
5	Newtown Creek	310
6	North River	170
7	Oakwood Beach	40
8	Port Richmond	60
9	Red Hook	60
	East	
10	26th Ward	85
11	Coney Island	110
12	Jamaica	100
13	Owls Head	120
14	Rockaway	45
	Total	1805

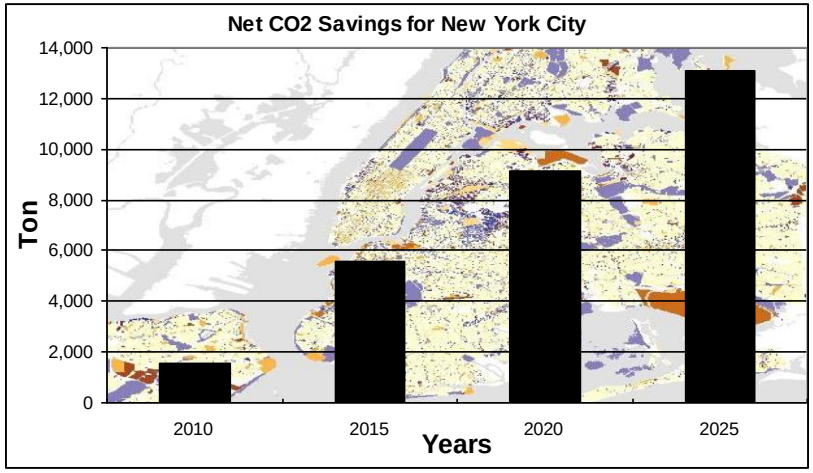


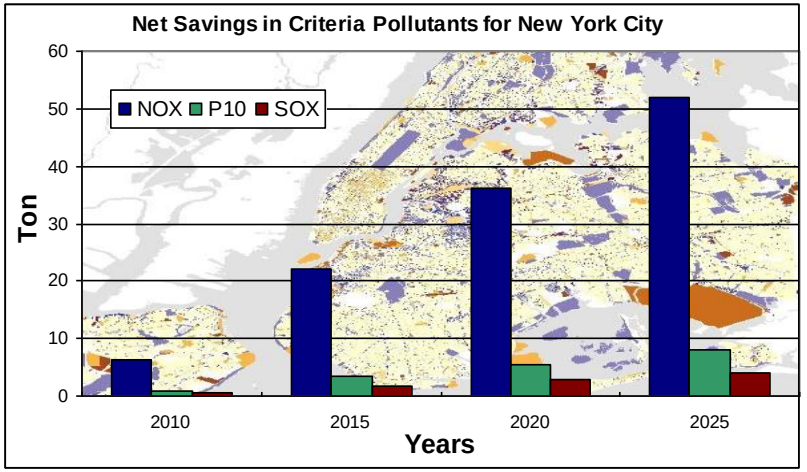
- 1.4 BGD treated
- 14 plants
- 93 pumping stations

Wastewater Treatment: Deploying More Fuel Cells

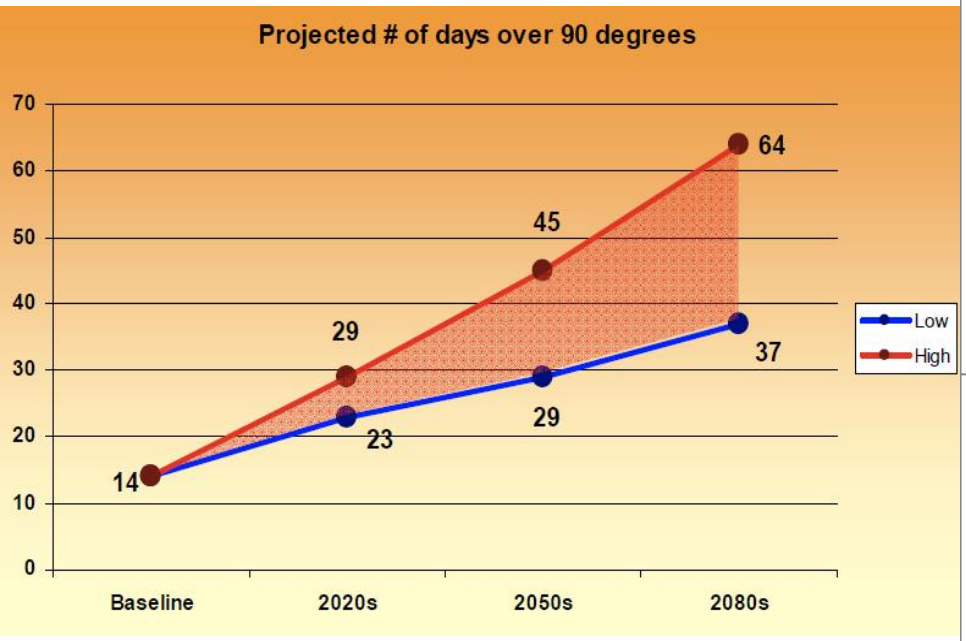
Location	No. of Fuel Cells	Size (kW)	Normal Operation	Project Cost*
Red Hook WWTP	2 - ADG	400	grid-parallel	$2 Mill'n
26th WWTP	2 - ADG	400	grid-parallel	$2 Mill'n
Hunts Point WWTP	3 - ADG	600	grid-parallel	$3 Mill'n
Oakwood Beach WWTP, Staten	1 - ADG	200	grid-parallel	$1 Mill'n
Total	8	1,600		

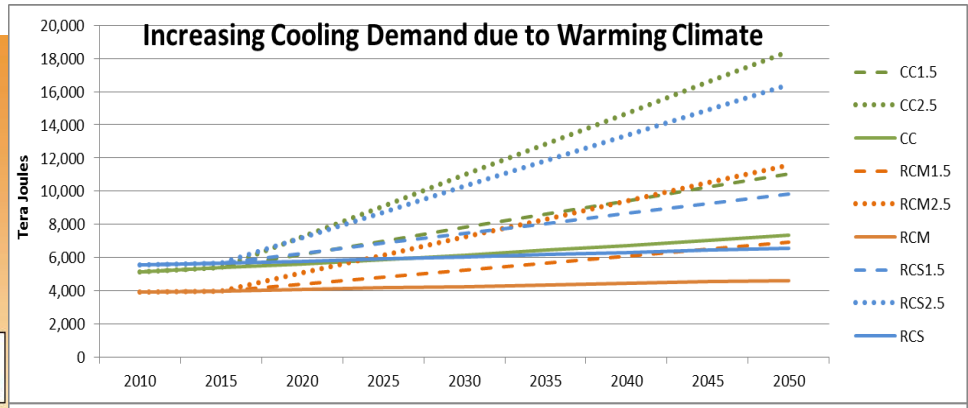


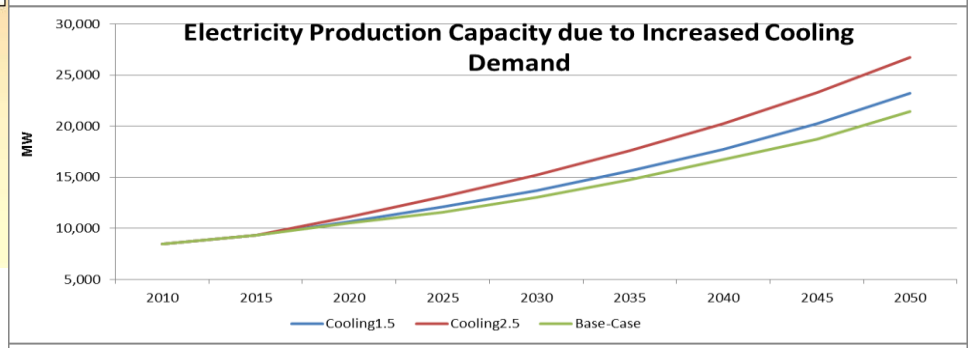


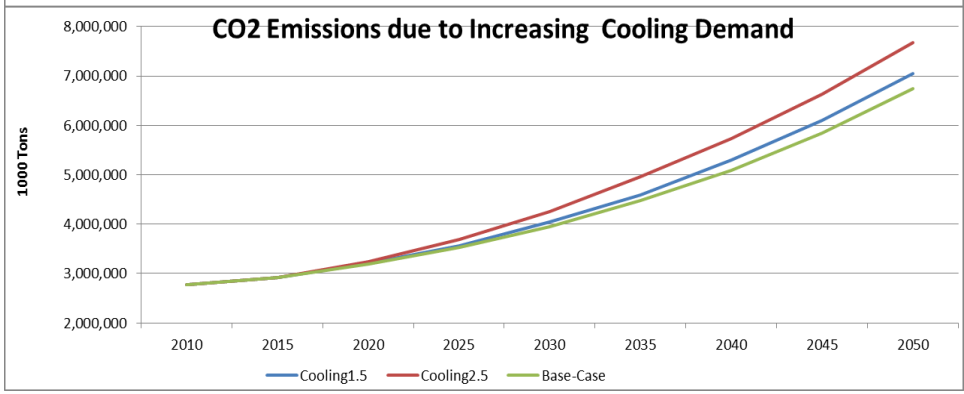


Warming Climate Impacts Cooling Demands in NYC





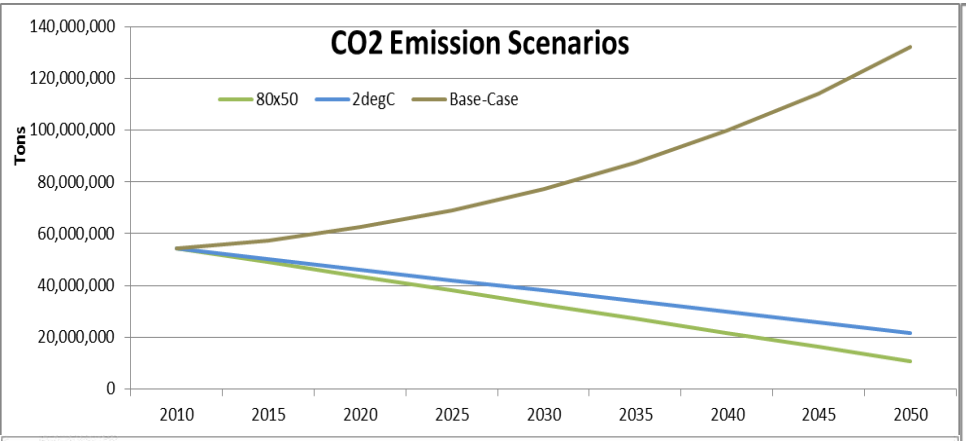


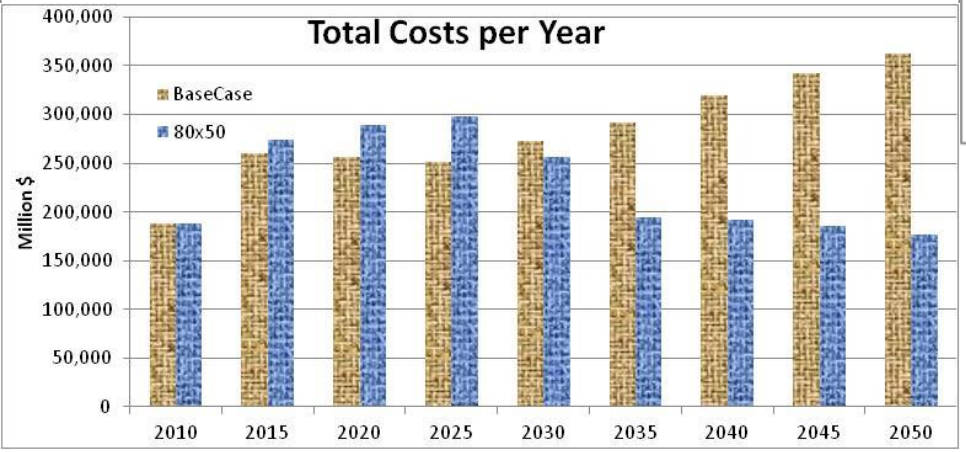


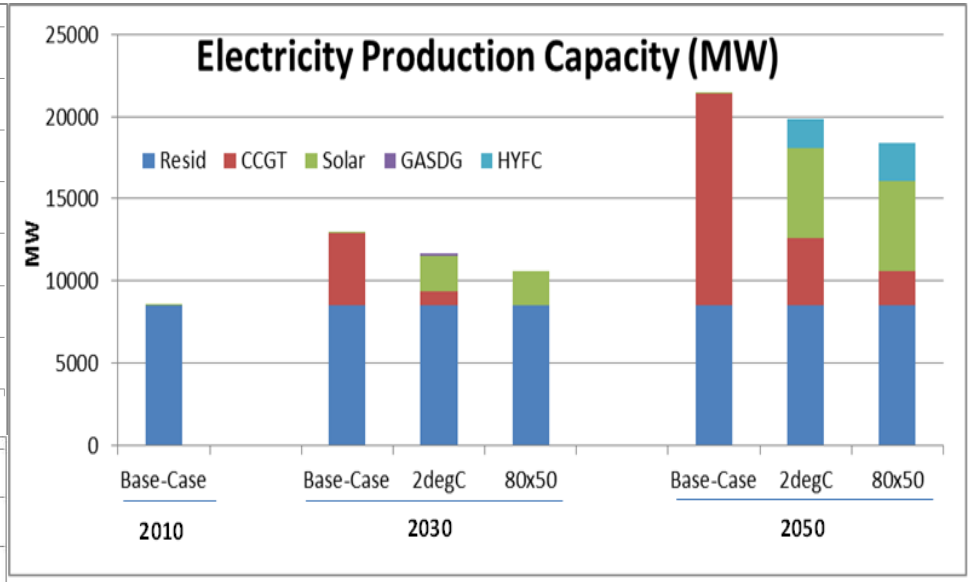
- 3 to 4 times more days per year over 90 degrees, approximately 3 to 4 times more heat waves a year – lasting up to 7 days each and more frequent, intense rainstorms.

Note: CC: Commercial Cooling, RCM: Residential Cooling-Multi Family, RCS: Residential Cooling-Single Family. Increased Cooing Demands by 1.5 times and 2.5 times respectively is indicated with separate dashed lines.

Reducing CO2 Emissions for Limiting Warming



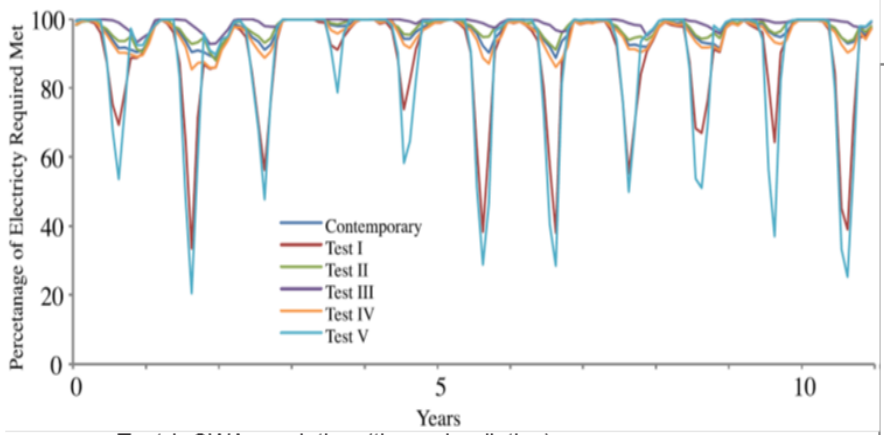




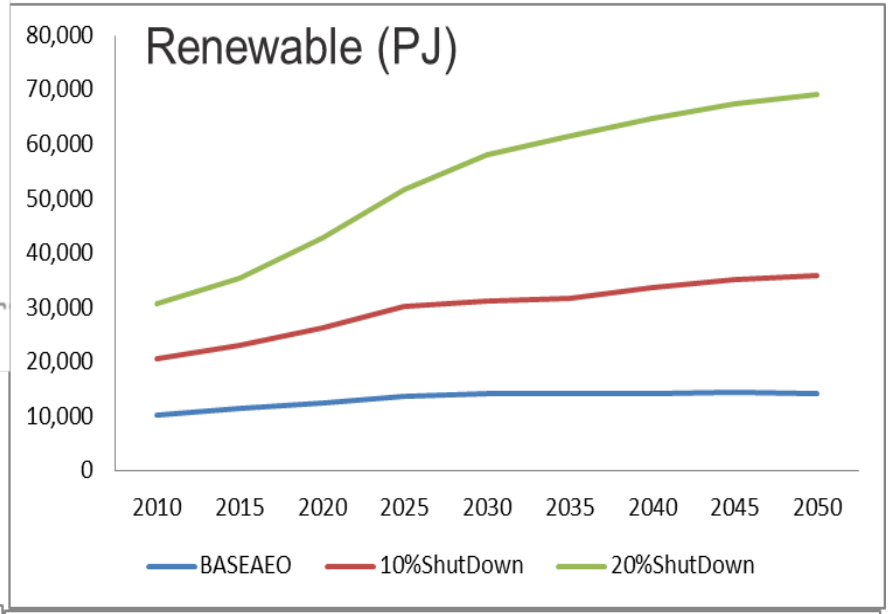
- *Stabilizing CO2 Emissions to 2ºC Warming* - Emissions decline to meet with 450ppm scenario @ 30% lower than in 2010 in 2035 and by 60% in 2050
- Reducing 80% CO2

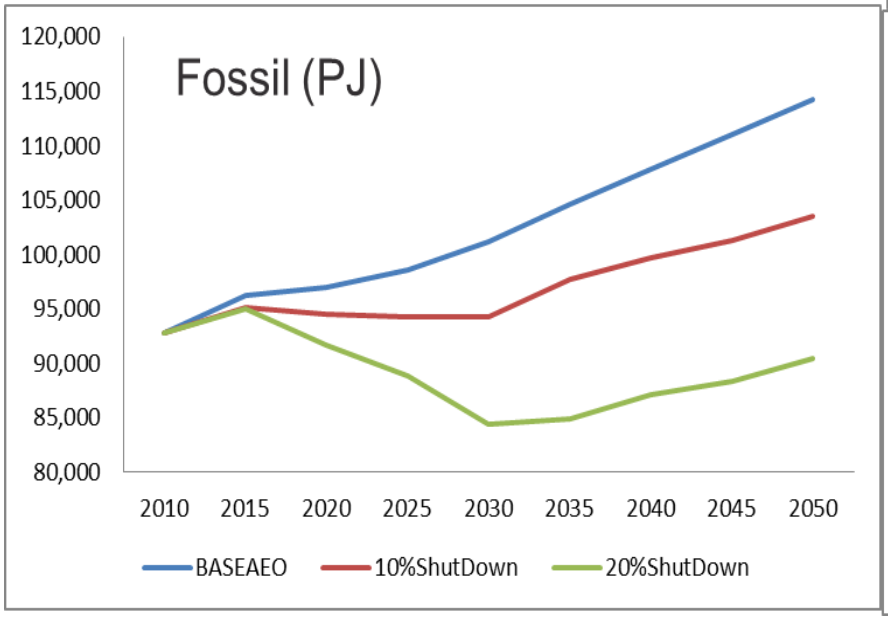
•35-50% buildings EE&C+ rooftop solar, DG, micro turbines and hydrogen fuel-cells.

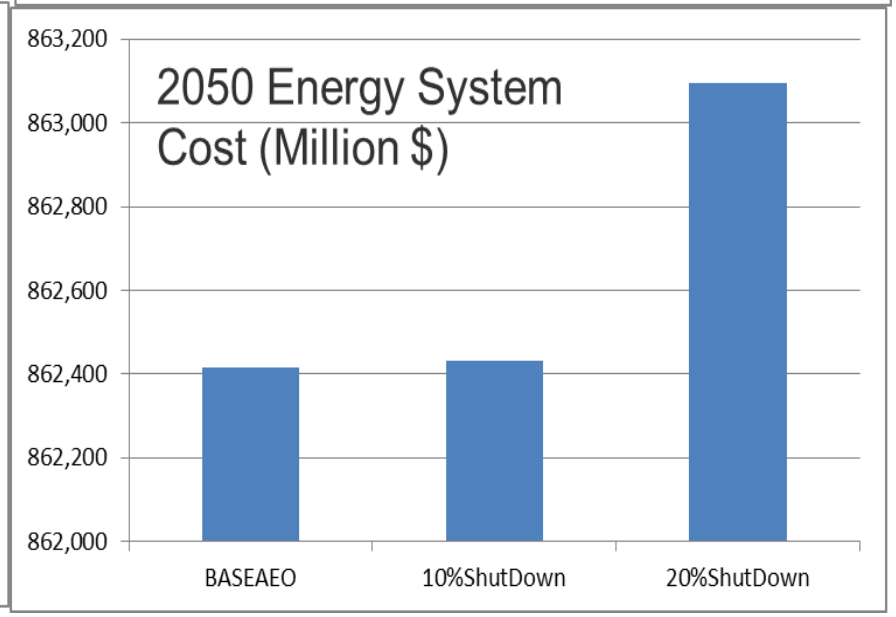
•Investments up to 50 billion $/yr



- Test I: CWA regulation (thermal pollution)
- Test II: future demand (technology BAU-2055)
- Test III: technology advancements
- Test IV: future climate (2.2° C)
- Test V: combined futures

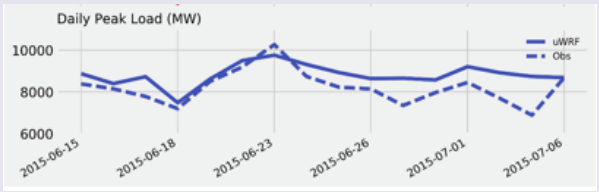






Projected Energy Demand → Energy-Driven Water Demand

Heat Wave-Driven Energy Demand



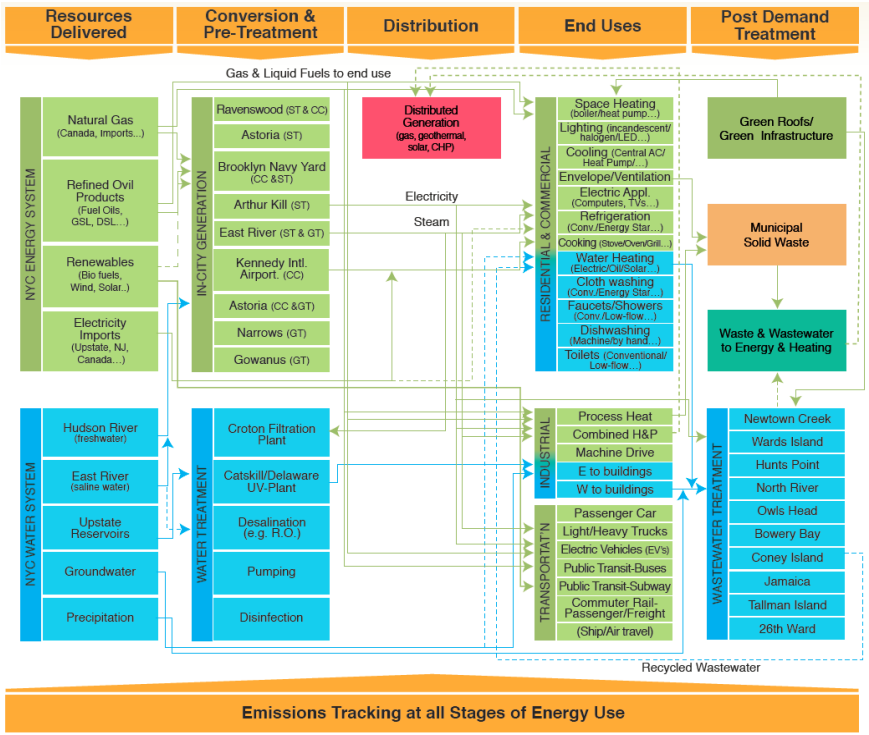
***Research task*: increase temporal resolution of water demand from annual scale to weekly/monthly scale**

Output :
Energy-driven Water demand and technology projections as function of policy, regulations, resources and economic constraints at weekly to monthly temporal

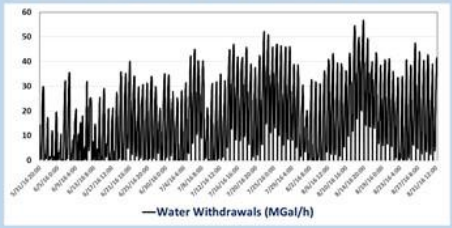
***MARKAL Modeling*:**

- Energy-Water Supply, Demand, Generation Portfolio Scenarios
- Policy, Incentives and Regulations
- Economics, Emissions
- Bottom-up Technologies
- Central v/s DG
- Time-of-use and Peaking
- WWTPs

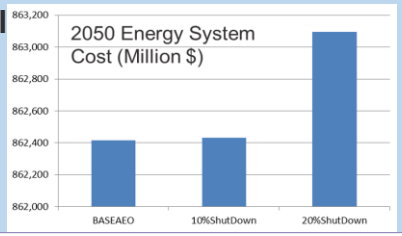
Existing Detailed NYC Energy-Water Model



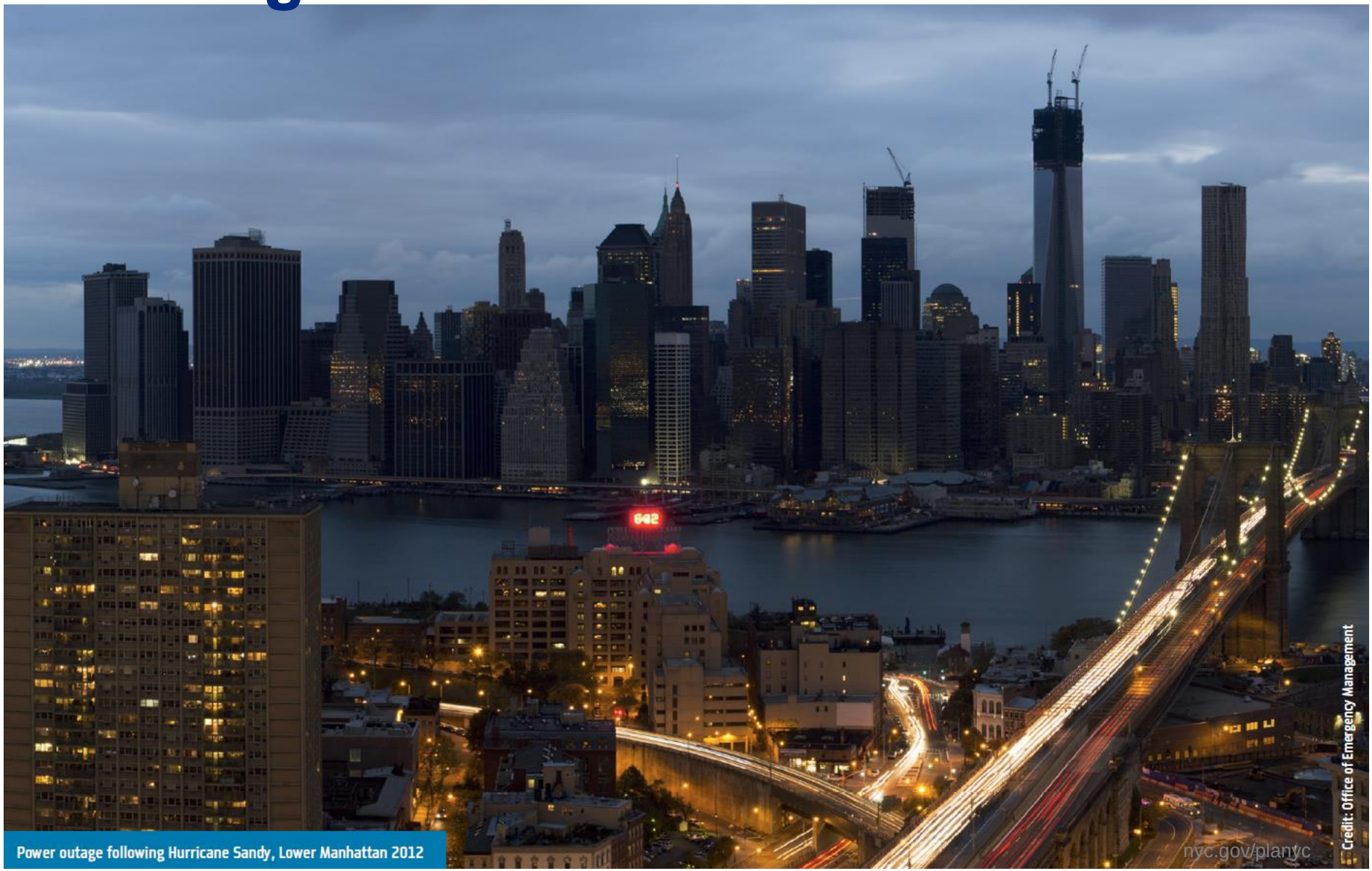
Heatwave-Driven Water Demand



Higher River Water Temperature Constrains Thermal Power Pl



Challenges Abound…



Power outage following Hurricane Sandy, Lower Manhattan 2012