# Integrated Energy and Environmental Planning with MARKAL Model

**Environmental Protection Agency – Region 2**

**Brookhaven National Laboratory**

**State University of New York at Stony Brook**

# Overview of the Presentation

- Relationship of Energy with Cities
- MARKAL Methodology to Address Urban Energy and Environmental Issues
- A Demonstrative Case-study: New York City


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# Relationship of Energy with Cities

EPA cites Adaptation as Key Strategy for Climate Change Response Dr. Joel Scheraga

Inside EPA February 9, 2007

# Energy in Today's World

- "Extending hope and opportunity depends on a ***stable supply of energy*** that keeps America's ***economy running*** and America's ***environment clean***" – the President of United State's State of the Union address 2007 (this is a global issue)
- "Warming of the climate system is unequivocal," the cause is "***very likely*** ***man-made***, and "***would continue for centuries***." – the Fourth Assessment Report - WG1-IPCC, February 2007

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# Energy and Cities

- Globalizing ***cities consume 75%*** of world energy
- Providing ***energy security and sustainable environment*** are major concerns for policymakers
  - U.S. Conference of Mayors' National Summit On Energy and the Environment, May 2006
  - London: The Mayor's Energy Strategy, February 2004
  - New York: PLANYC 2030, December 2006
  - Large Cities Climate Summit – C20: 2005, C40: 2007
- Energy & Environmental systems in agglomerated urban regions consist of ***highly interconnected subsystems***
- Planning for these systems are comprised of two levels:
  - Analysis of the overall local or regional systems for ***long-term strategic planning***
  - Analysis and optimization of ***subsystems***

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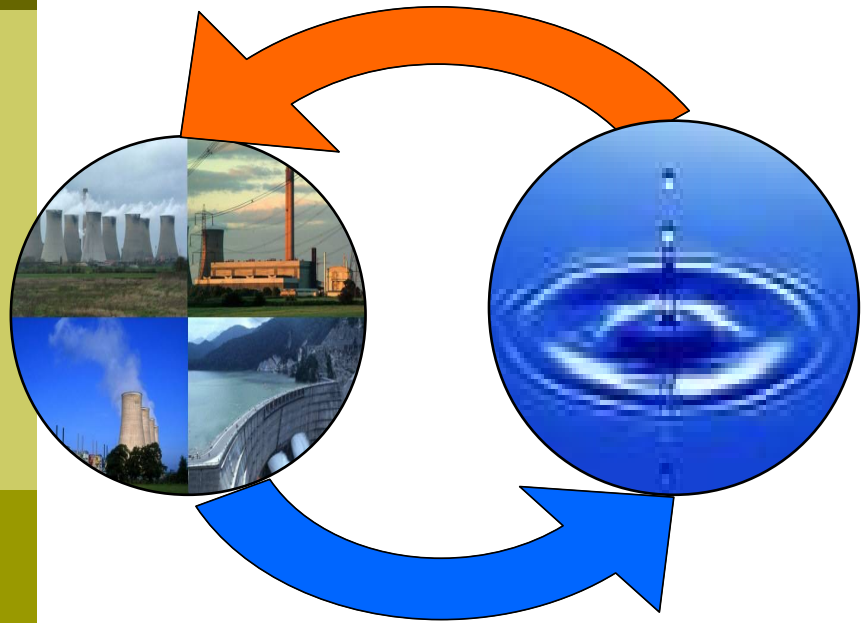
# Energy-Water Nexus

## Energy and water are inextricably linked

### *Water for Energy*



- About 54% of U.S. generating capacity comprised of one-through cooling (requires reliable, large volumes of water
- In 2000, 39% of U.S. water withdrawals were for thermoelectric power production[3]
  - 136 BGD-freshwater withdrawals
  - 59 BGD- seawater withdrawals
  - 3 BGD-water consumption (about 20% of nonagricultural water consumption)

### *Energy for Water*

- Globally, 7% of the total energy consumed is for water delivery
- Worldwide, 2-3% of energy is consumed for water conveyance and treatment to serve urban populations and industry[1].
- Water heating is typically the 2nd largest user of energy in the home (19% of home energy use) (according to Rocky Mountain Institute)


- ASE (Alliance to Save Energy). (2002). *Watergy: Taking Advantage of Untapped Energy and Water Efficiency Opportunities in Municipal Water Systems*, report by K James, SL Campbell, CE Godlove, ASE, Washington, D.C. 2. EIA (U.S. Department of Energy-Energy Information Administration). (2005). *Annual Energy Outlook 2005*, report prepared by JJ Conti, PD Holtberg, JA Beamon, JM Kendell, AS Kydes, U.S. Department of Energy-EIA, Washington, D.C. 3. USGS Circular 1268 *Estimated Use of Water in the United States in 2000 (2004)*

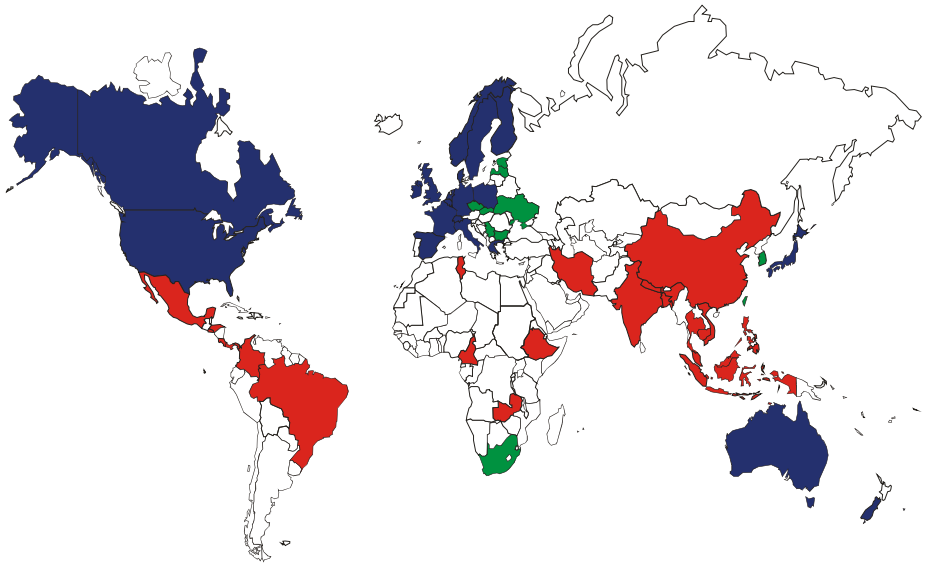
# MARKAL Methodology to Address Urban Energy and Environmental Issues

NYC MARKAL to reduce GHG's

Electricity,Water and Solid Waste Nexus

# MARKAL as an Energy & Environment Planning Tool

- ***Well established state-of-the-art tool*** for energy systems analysis, developed at BNL in 1970s.



Total OECD = 22

Total Developing = 23

Total Other = 13

- ***30 years of development*** under the auspices of the International Energy Agency and the US Department of Energy
- Approximately 120 user institutions in ***more than 50 countries***
- ***Flexible and transparent*** framework - allows use of different features depending on modeling needs
- Methodology is ***well documented***

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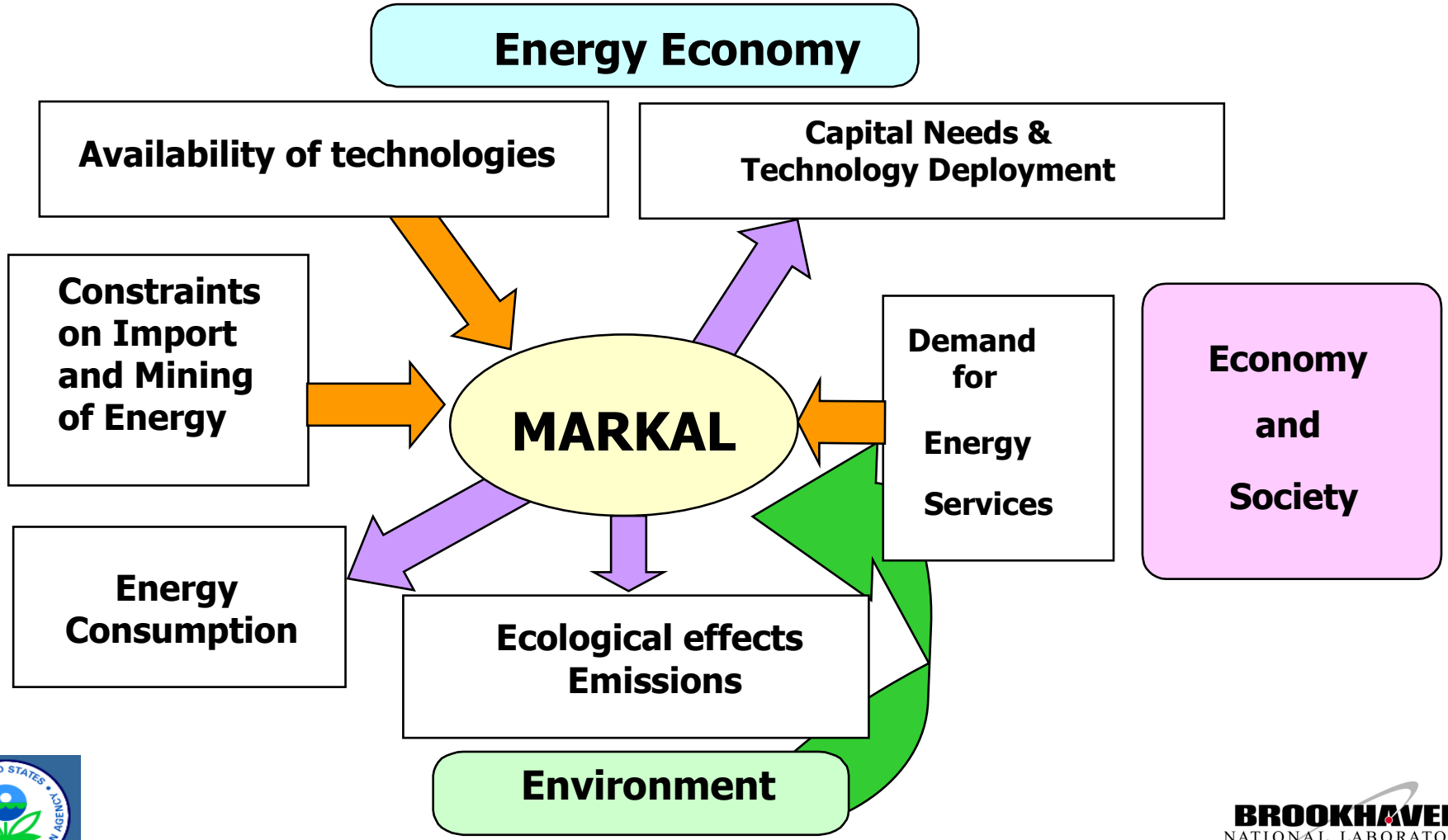
# MARKAL Framework Overview

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# MARKAL Modeling Framework

- ***MARKAL*** (MARKet ALlocation) is an ***integrated*** energy, environment and economic model, to ***examine market potential*** for energy technologies over a short-, medium- and long-term horizon under ***alternative policy scenarios*** within the entire energy system.
- Utilizes a ***bottom-up*** approach to represent and characterize ***technology specific portfolios at subsystem level*** – highlights synergies, offsets and feedback effects
- Facilitates Urban Planners in selecting ***cost effective technology mix*** over the entire system based on ***life cycle accounting***
  - Involve all ***relevant interest groups*** in the planning process
  - Set-up a plan for ***continuous improvement and monitoring***

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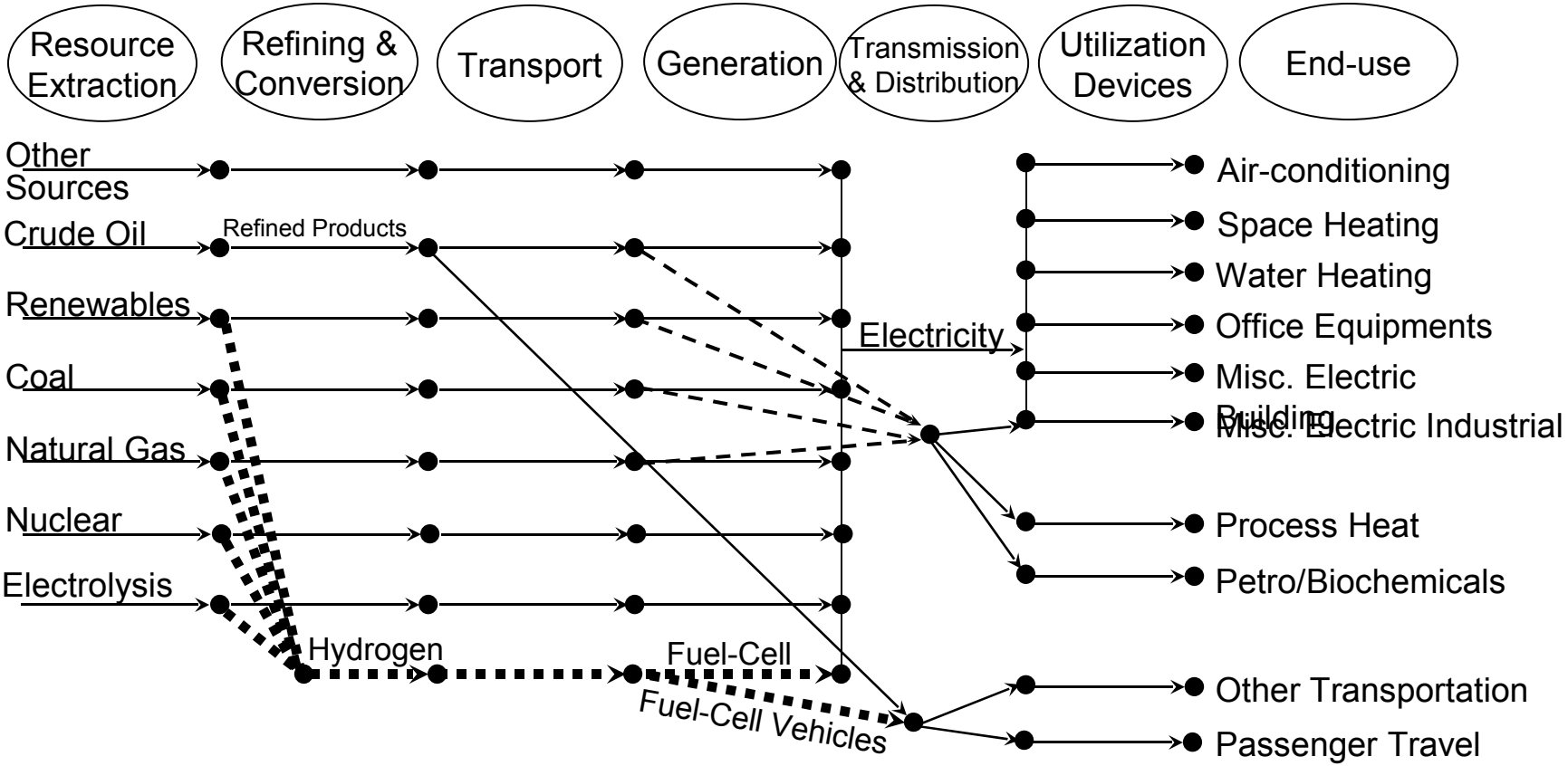
# Demonstrative MARKAL Reference Energy System



# US National Energy Planning Applications of MARKAL

Support for ***3 US Department of Energy offices***

- Analyze the long-term market ***competitiveness of R&D portfolio***
  - Office of Energy Efficiency & Renewable Energy
  - Office of Nuclear Energy
- Assess competitiveness of ***alternative and boutique fuels*** for the Office of Policy and International Affairs
- Options and tradeoffs of alternative ***hydrogen production infrastructure pathways*** with respect to demand, technology cost, regional mix, and feedstock prices
- Develop and demonstrate the utility of ***analysis at the Census Region level***
- Provides platform to model DOE programs such as ***Global Nuclear Energy Partnership***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# Global and Local Applications of MARKAL

- U.S. Environmental Protection Agency
  - ***New York City*** energy efficiency and urban heat island mitigation project
  - Assisting ***Texas*** institutions for building energy system models
  - ***Taiwan*** national energy model and policy analysis
  - ***Central American*** energy and environment cooperation
- ***Hong Kong*** MARKAL model and supporting policy analysis
- Development of ***Kuwait*** energy system and extensive refinery model
- Development of ***Mongolian*** MARKAL and training government officers on MARKAL modeling
- Enhancement of ***Korean*** MARKAL and training Korean government officers and energy professionals on MARKAL modeling
- Assisting the Government of ***India*** on Eco-Cities project

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# A Demonstrative Case-study: New York City

# NYC MARKAL Model

- Multi-region structure to measure the impacts of ***Energy Star technologies and Urban Heat Island measures*** on the electricity demand at the sub-station level
- Network capability to model ***central and distributed generation plants, transmission & distribution and sub-station peak load characteristics***
- Integrated framework for evaluating NYC system-wide effects in ***electricity flow, peak load, criteria and GHG emissions***, due to changes in hot pockets/substations

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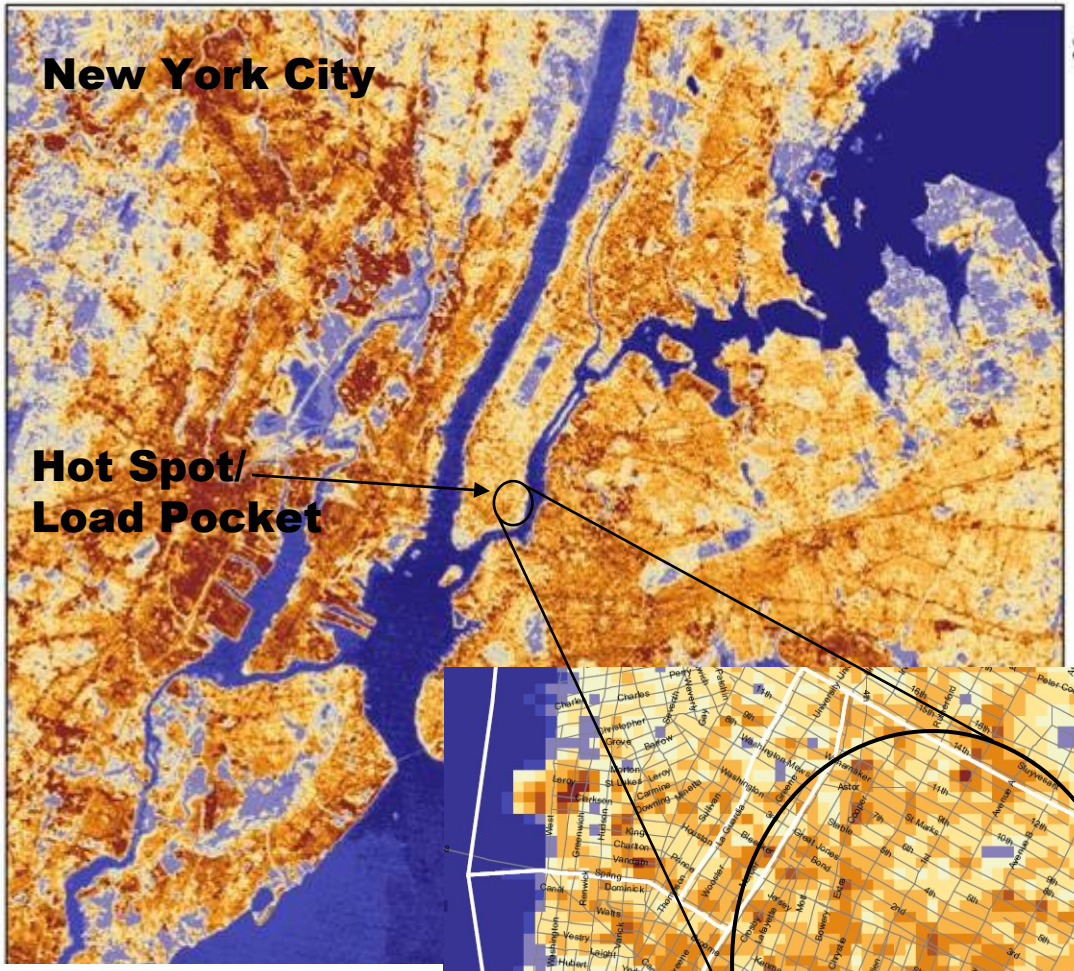
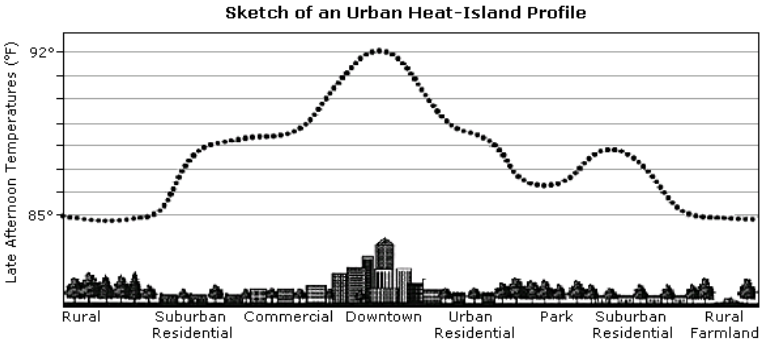
# Study Area

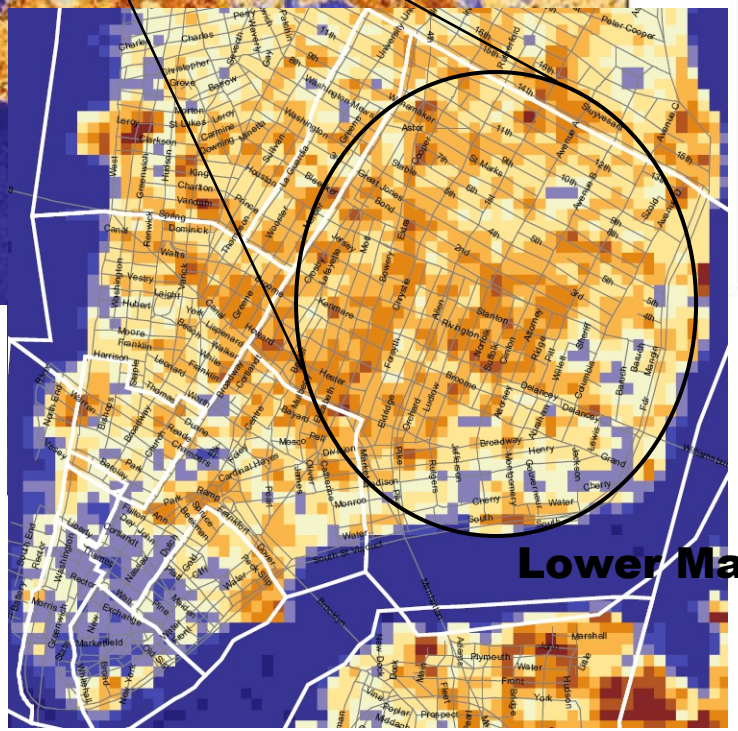



SURFACE TEMPERATURE
Landsat ETM
July 22 2002
10:30 AM

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

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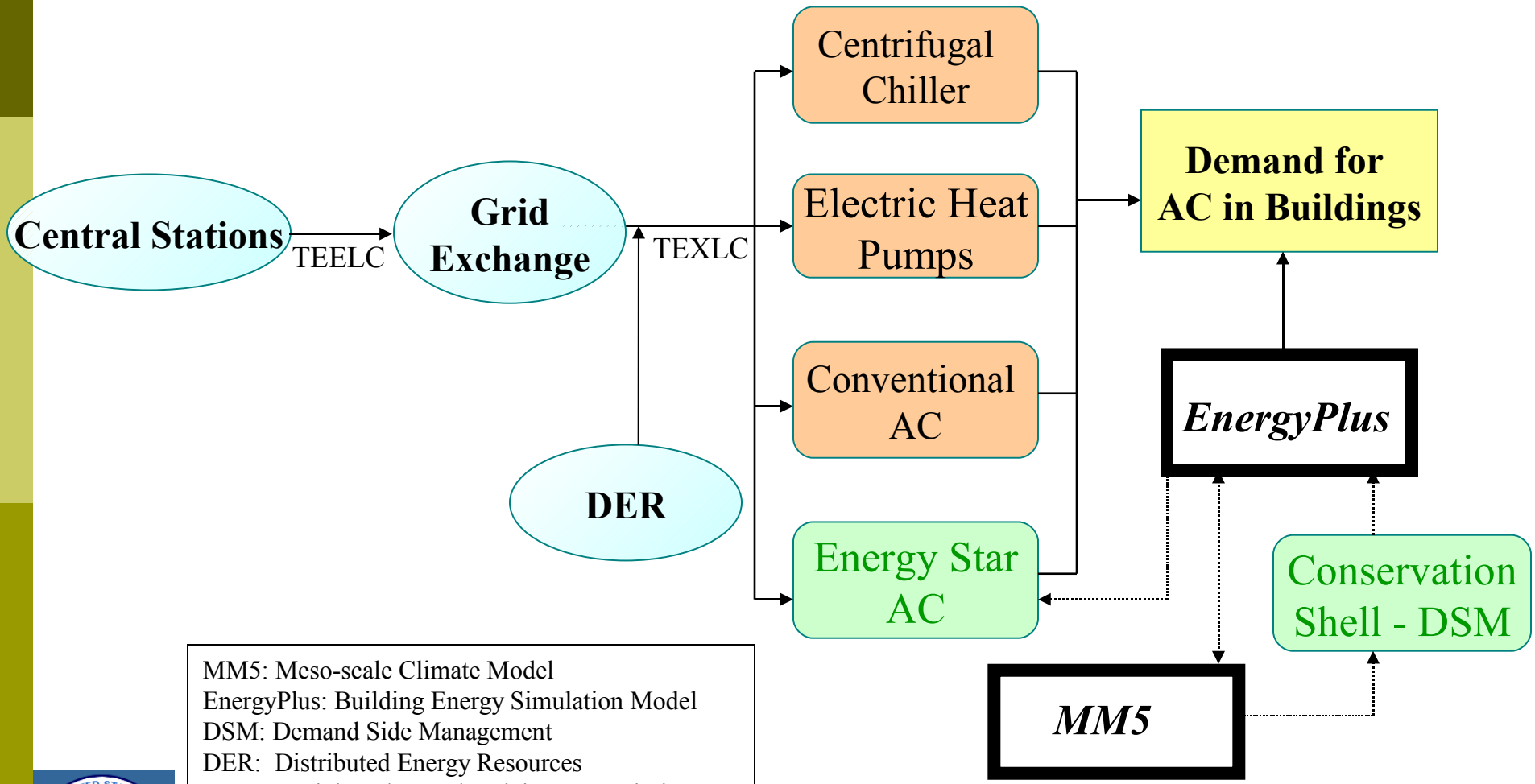
# MARKAL-EnergyPlus-MM5 Interactions




MM5: Meso-scale Climate Model
EnergyPlus: Building Energy Simulation Model
DSM: Demand Side Management
DER: Distributed Energy Resources
TEELC: High Voltage Electricity Transmission
TEXLC: Low Voltage Electricity Transmission

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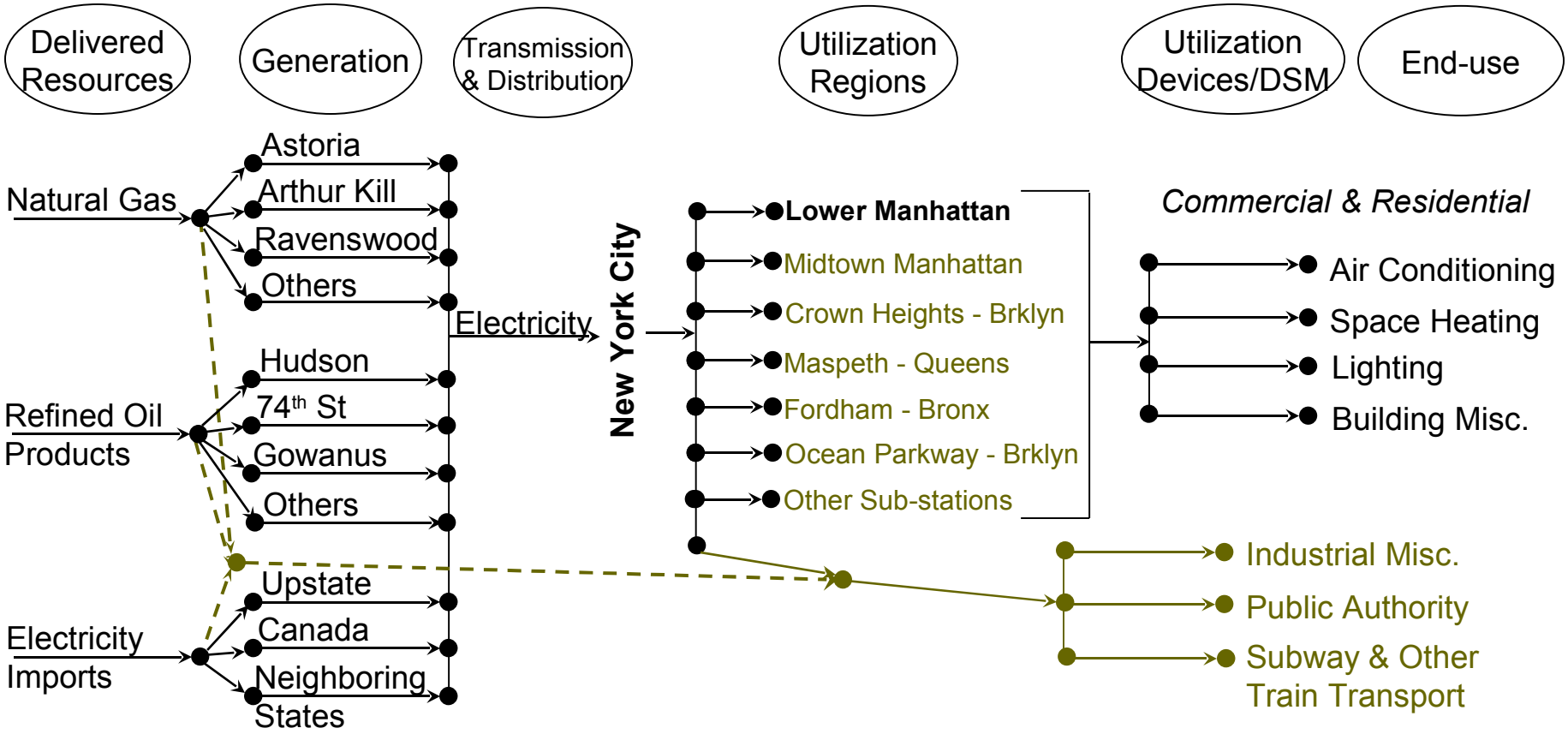
# NYC MARKAL Modeling Framework




- Builds on extensive plant level information from the Energy Information Administration and the Environmental Protection Agency
- Time of the day peak-load was modeled on the basis of seasonal variability

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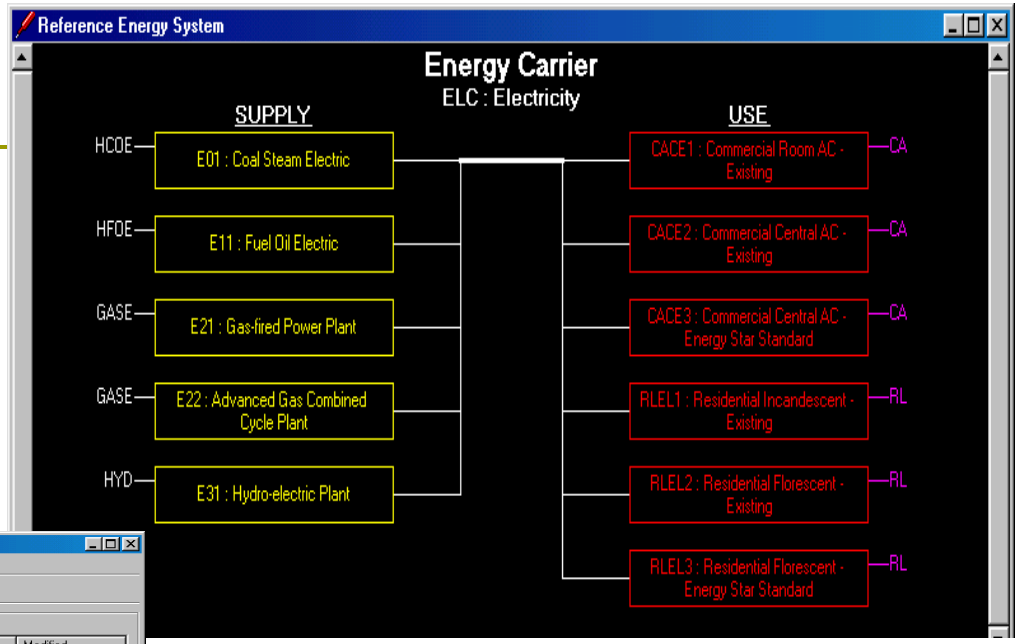
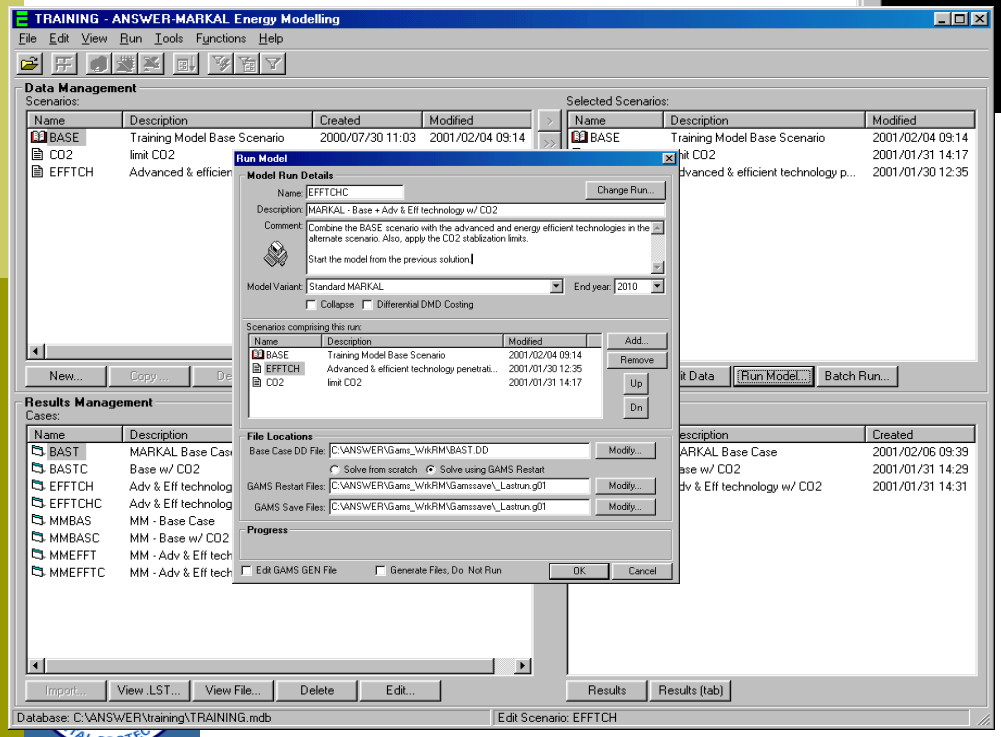
# MARKAL Modeling System

## RES Diagram

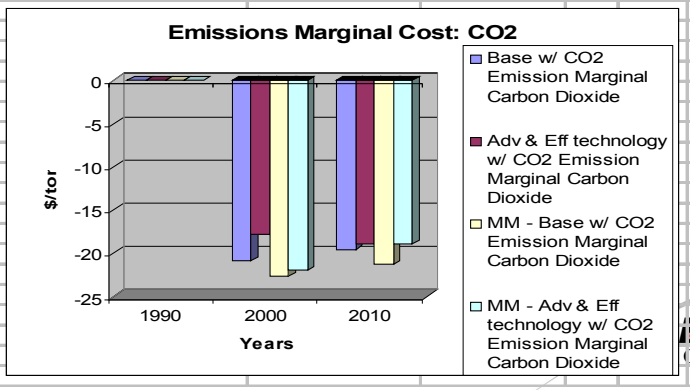



## Data Management & Scenario Development




## Output w/ Excel Graph

| Case | Parameter | Emission | 1990 | 2000 | 2010 |
|---|---|---|---|---|---|
| Base w/ CO2 | Emission Marginal | Carbon Dioxide | 0 | -20.91 | -19.54 |
| Adv & Eff technology w/ CO2 | Emission Marginal | Carbon Dioxide | 0 | -17.81 | -18.92 |
| MM - Base w/ CO2 | Emission Marginal | Carbon Dioxide | 0 | -22.62 | -21.25 |
| MM - Adv & Eff technology w/ CO2 | Emission Marginal | Carbon Dioxide | 0 | -21.92 | -18.91 |



# EnergyPlus Building Energy Simulation

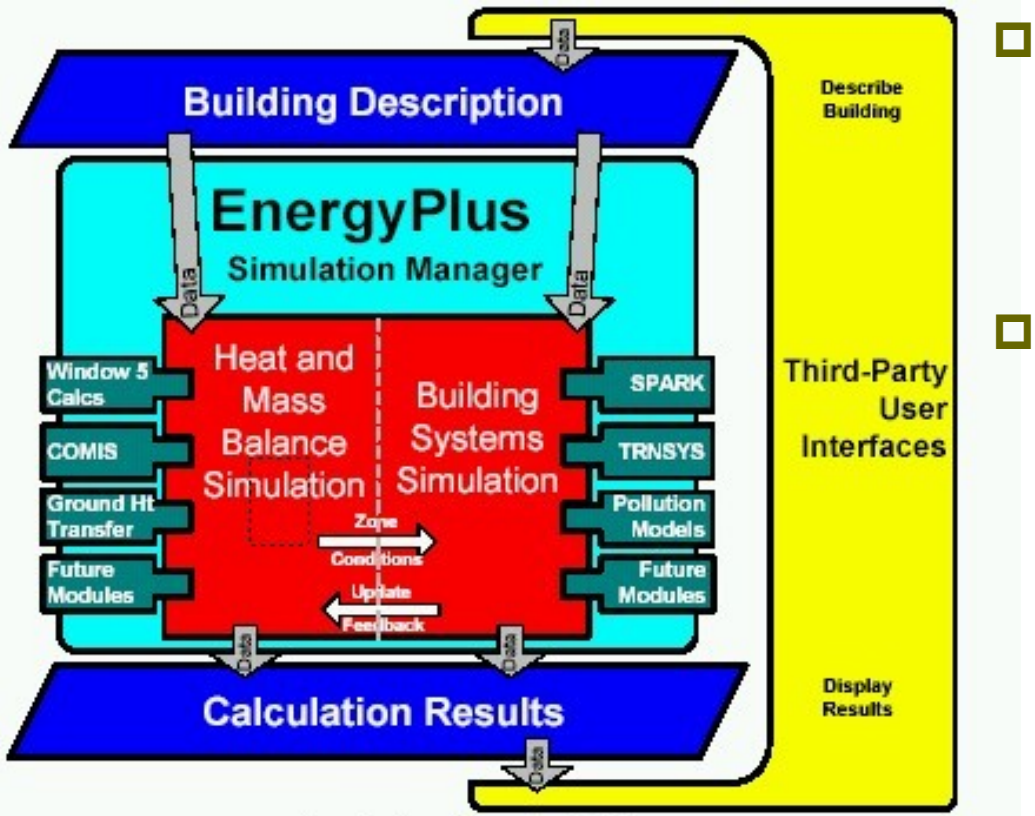



Figure 1. EnergyPlus -- the big picture

- Builds on the most popular features and capabilities of BLAST and DOE-2
- Calculates HVAC loads to maintain thermal control setpoints, based on the building's physical make-up, mechanical systems, environmental conditions, etc.

Web: www.eere.energy.gov/buildings/energyplus/

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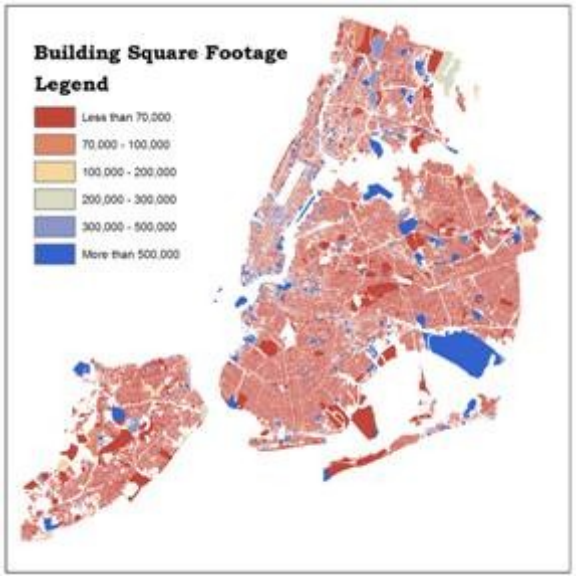
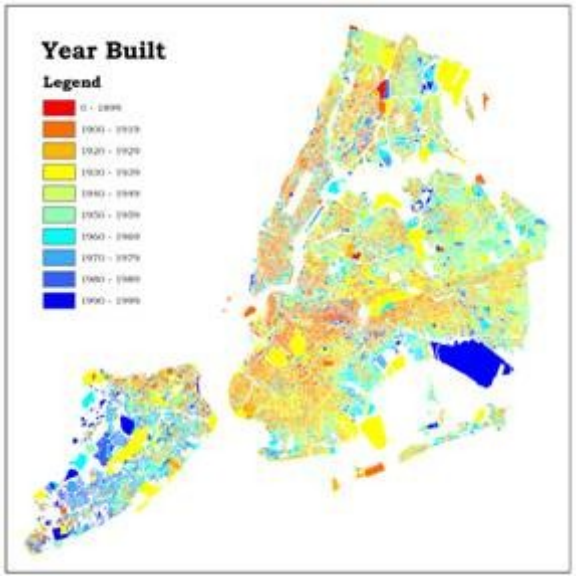
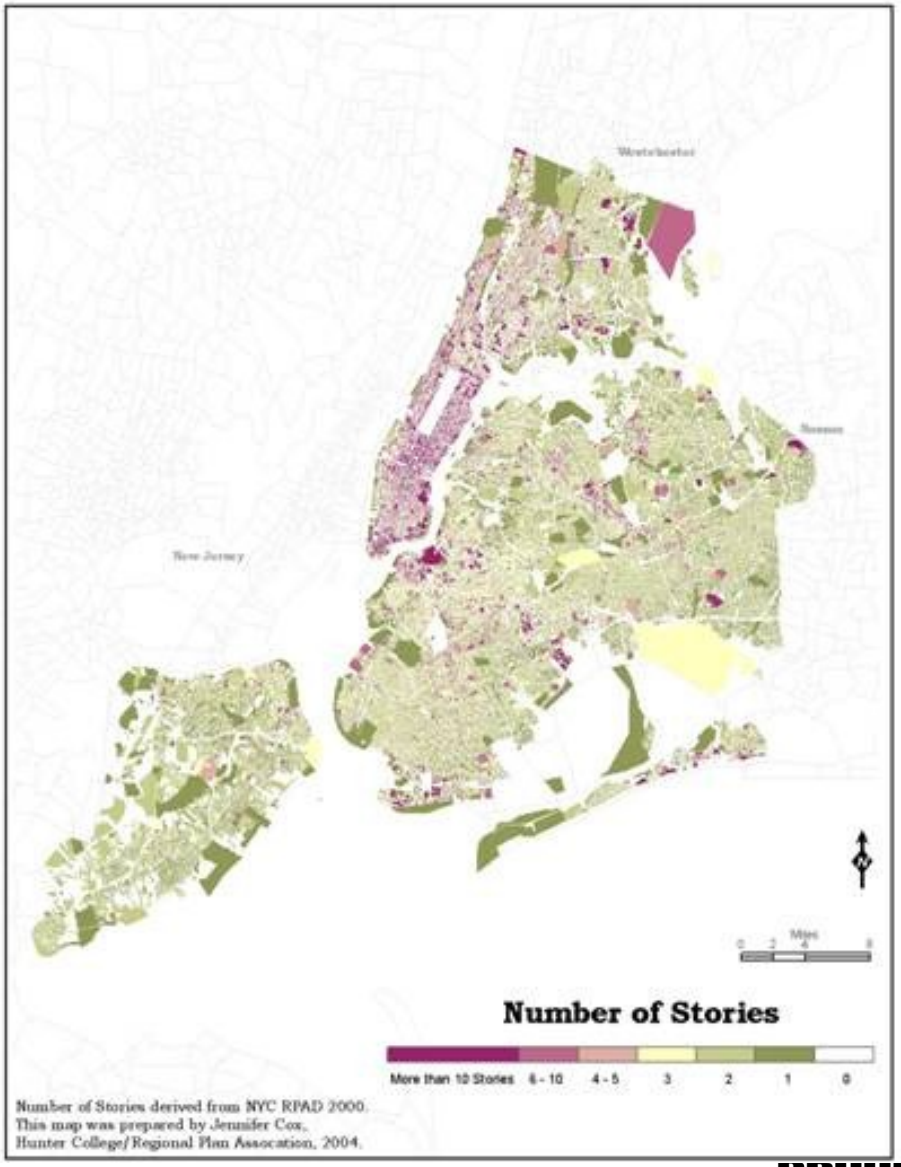
# EnergyPlus/UHI: Building Mix




Maps Source: NYSERDA UHI Study

# Building Inventory to Cooling Demand

| *COOLING DEMAND* | Older 3 | Older 10 | Glass 3 | Glass 10 |
|---|---|---|---|---|
| *Peak* | | | | |
| *buildings* | - | - | - | - |
| base (kW / sq meter) | 0.019 | 0.066 | 0.028 | 0.095 |
| deg & roof (kW / sq meter) | 0.016 | 0.057 | 0.021 | 0.075 |
| reduction | *-16%* | *-13%* | *-23%* | *-21%* |
| *Daily* | | | | |
| *buildings* | - | - | - | - |
| base (kW / sq meter) | 0.30 | 1.01 | 0.38 | 1.27 |
| deg & roof (kW / sq meter) | 0.24 | 0.83 | 0.25 | 0.88 |
| reduction | *-20%* | *-18%* | *-33%* | *-31%* |

- Prototype buildings were selected from the building inventory of the area to measure benefits of various mitigation measures

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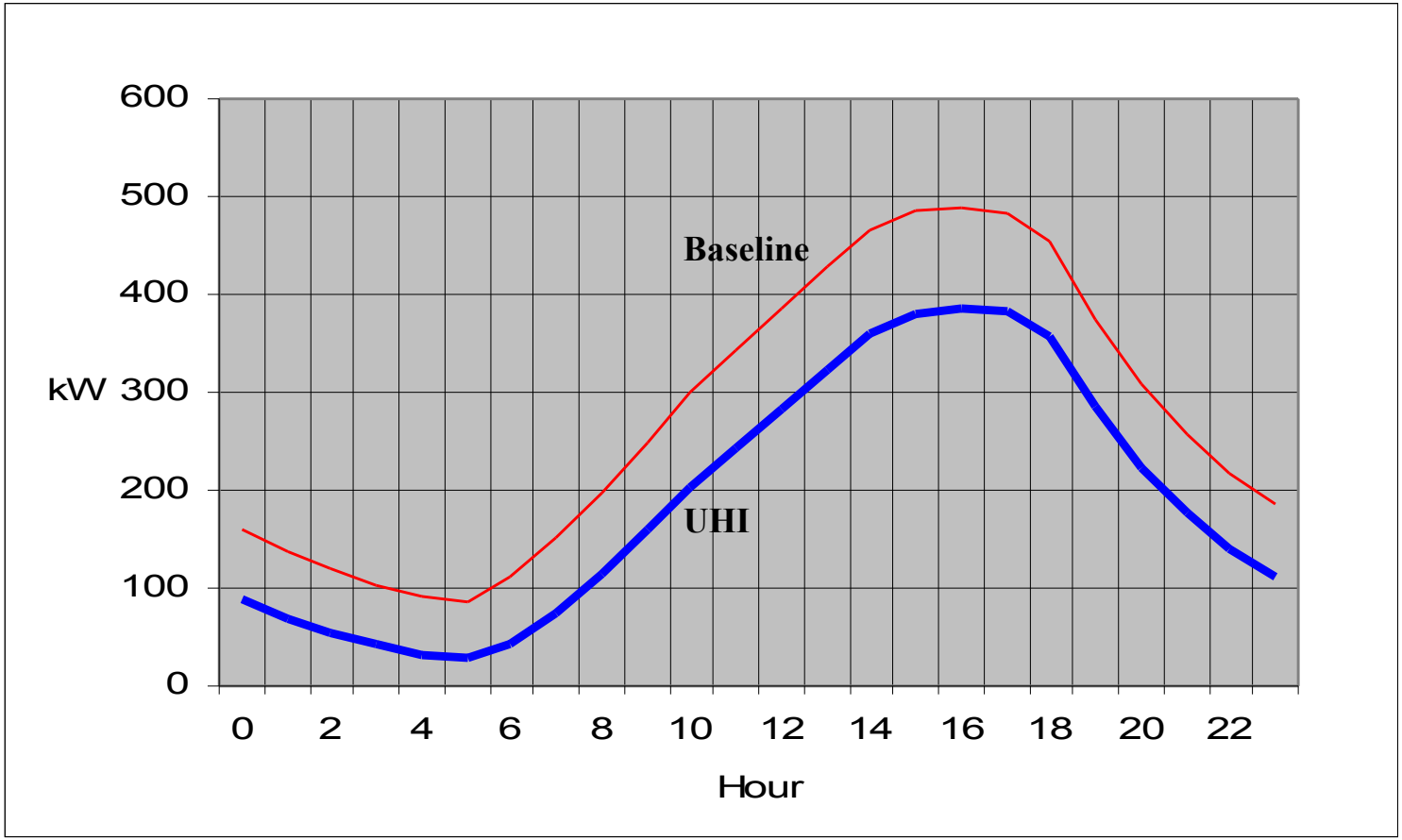
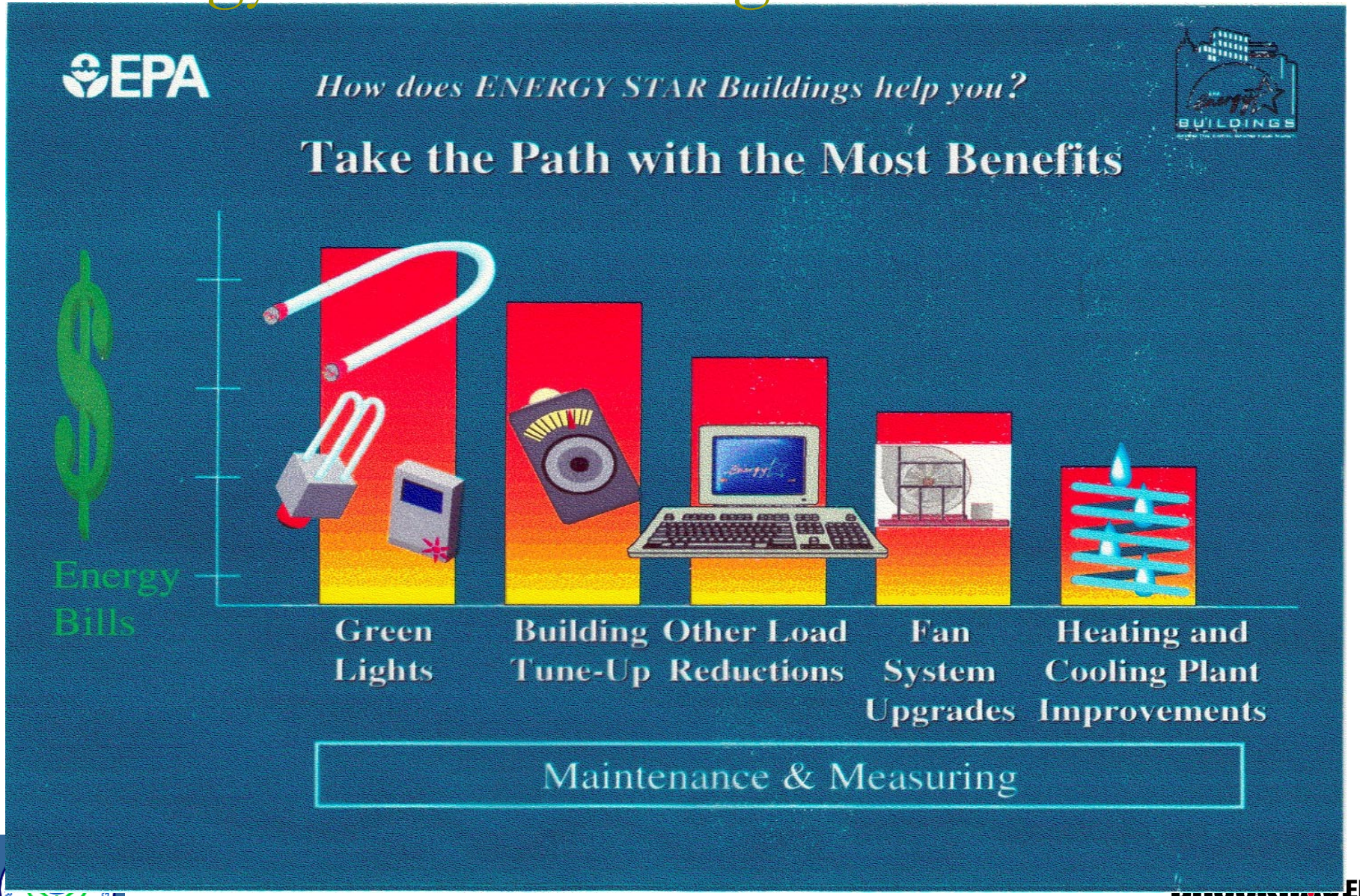
# EnergyPlus Load Schedule- time of day



# Energy Star Technologies



# Key Benefits to the City

- **Carbon**
  - xx% reduction in carbon from Municipal facilities/sources by 2010
  - xx% reduction in carbon from the entire city by 2030
- **Energy**
  - Reduction in energy use per capita
  - Reduction in energy use intensity
  - Increased use of renewable resources
  - Decreased reliance on imported fossil fuels
  - Increased use of efficient appliances/ green technology/etc.
  - Decrease in energy for transportation
- **Sustainability**
  - Increase in recycling of solid waste
  - Efficient and reliable transportation
- **Society**
  - Provide a clean environment for all city residents
  - Keep energy costs as low as possible

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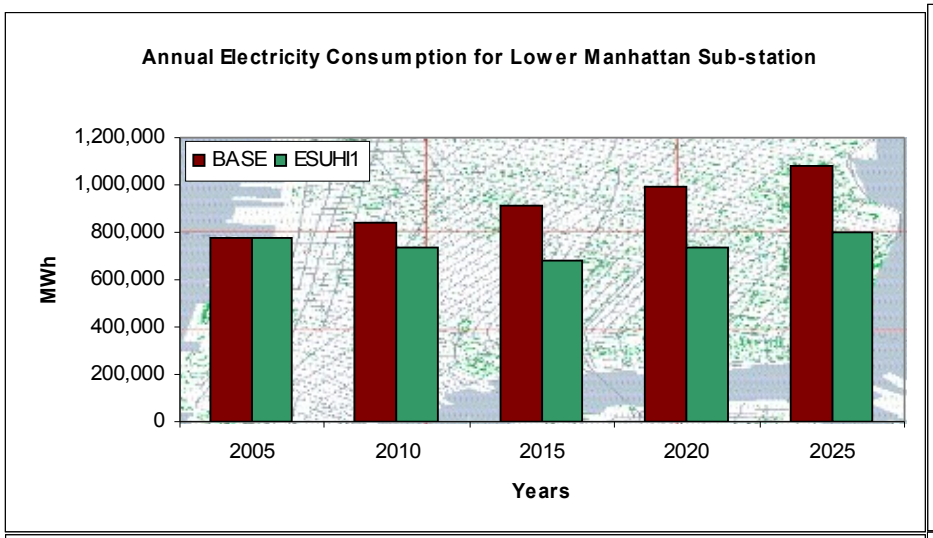
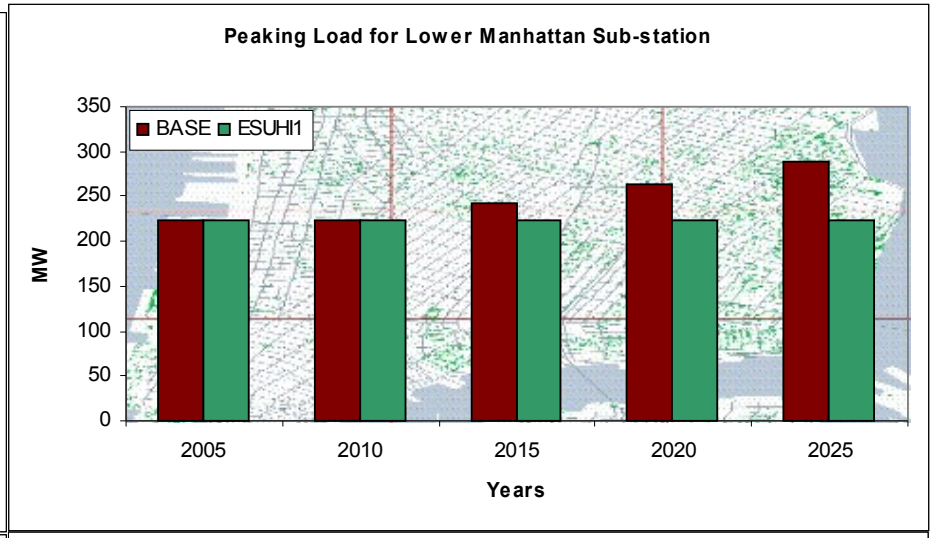
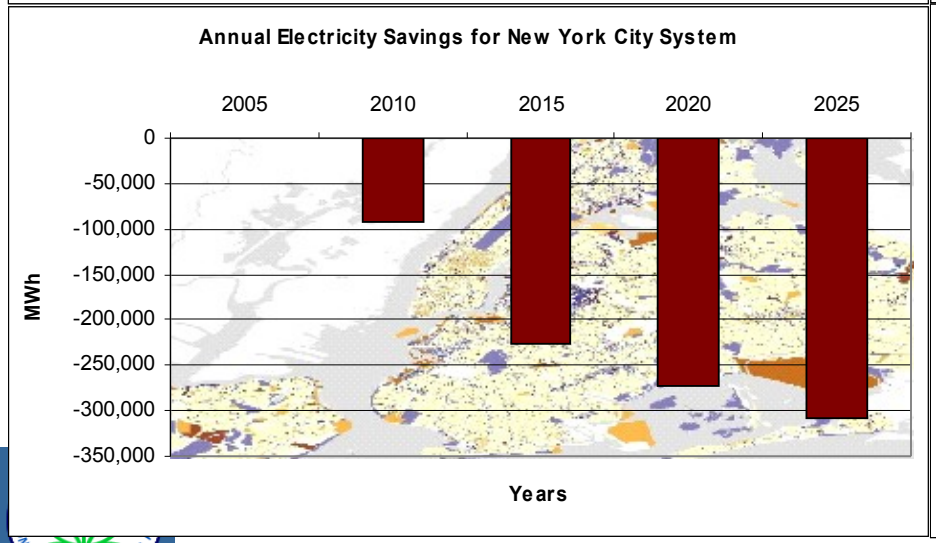
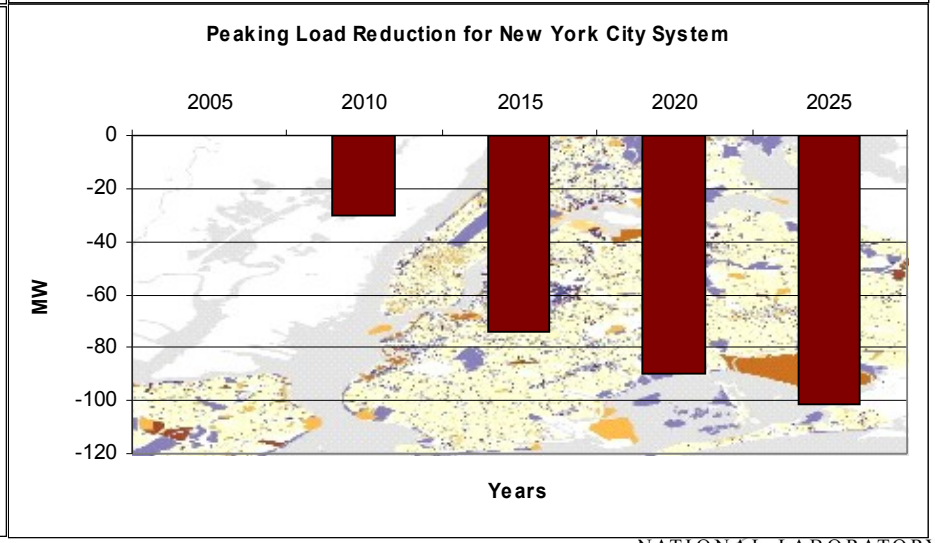
# Impacts of UHI Measures and Energy Star Technologies



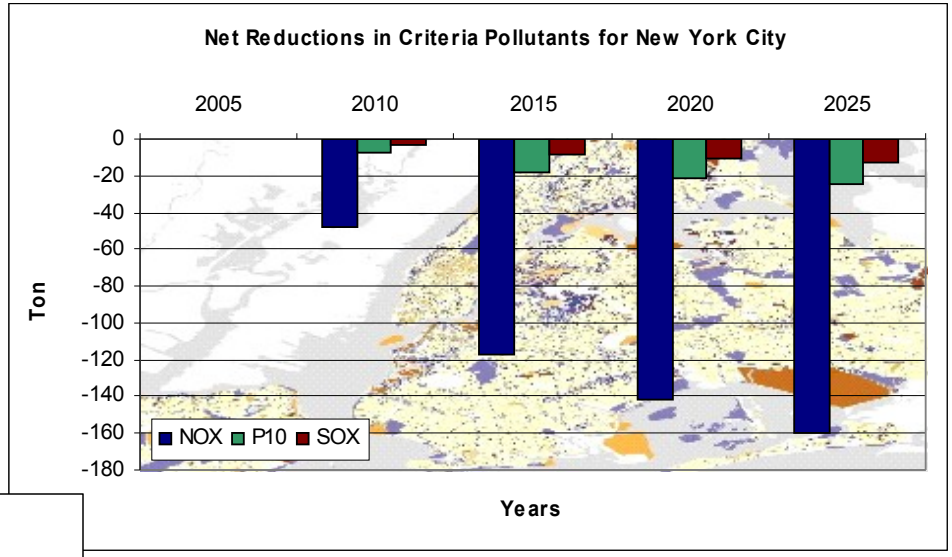



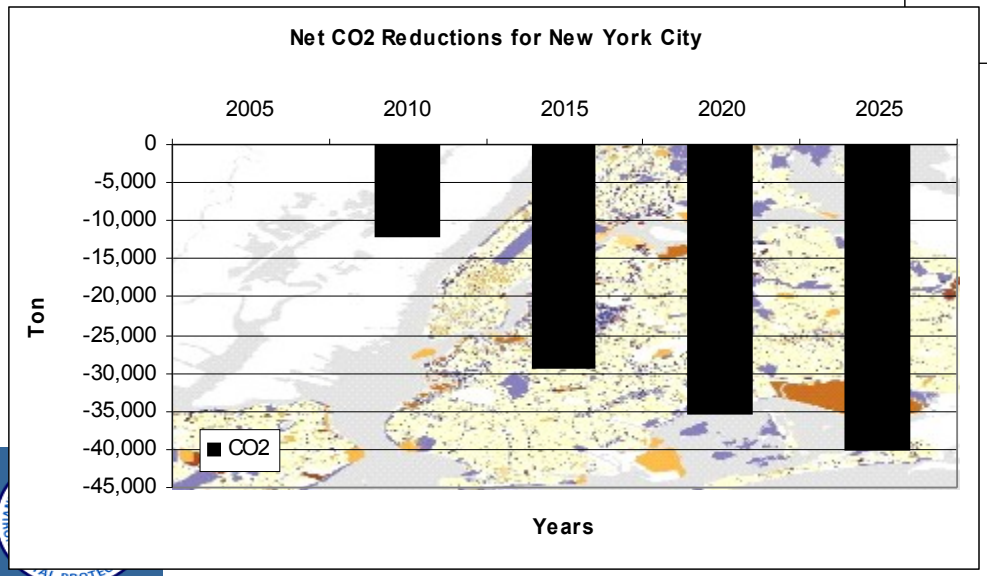




UHI – Urban Heat Island effect

# NYC: Emission Reductions due to UHI Measures and Energy Star Technologies

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# Summary

- Urban system ***responses*** of alternative strategies are ***complex*** and need a ***systematic integrated analysis***
- Adaptation to such a new concept can lead to ***cost-effective solutions*** to the long-term energy security and the environmental sustainability
- BNL's ***longstanding research and experience brings a paradigm shift*** in local energy and environmental planning
- Such a ***comprehensive framework*** will provide us with a ***robust tool*** to address an ***upcoming need*** to tackle pressing urban energy and environmental ***issues worldwide***

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