Cornell University

NOx emissions and near-source air quality impact of distributed electricity generation

K. Max Zhang

Energy and the Environment Research Laboratory

Sibley School of Mechanical and Aerospace Engineering

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- Research Group members: Bo Yang, Xiyue Zhang, and Zheming Tong

Main Messages

- A better estimate of the NOx emissions during demand response (DR) events is needed
- "Green DR" is key to achieving the co-benefits of power system reliability and better air quality during high electric demand days
- Siting really matters for distributed generation (DG)
- Considering ground-level only concentrations in permitting DG may not be sufficient for protecting public health

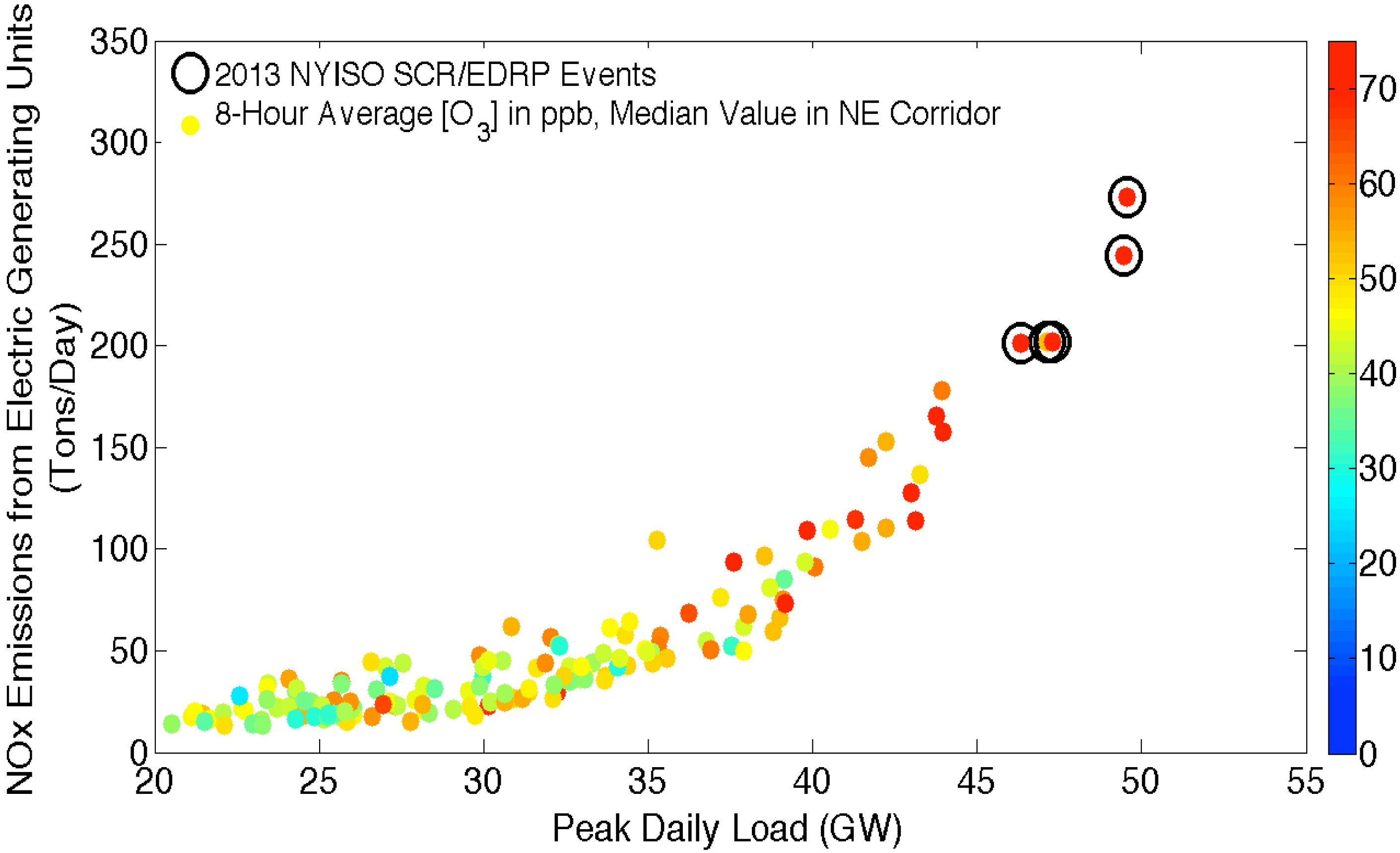
A “peak” problem

- Context: High electric demand days
  - Energy: Power systems is stressed
  - Economics: highest electricity prices
  - Environment: “Double Threats”, i.e., Air pollution (O_3, PM, etc.) and Heat

- Can we achieve co-benefits of power system reliability and healthy air quality?
  - Challenges: All available generation resources already dispatched
  - Demand Response (DR) is the key
    - Maintain reliability
    - Potentially reduce emissions

Zhang and Zhang (2015) ES&T, 49(3): 1260-1267

May 1 – September 30, 2013



- Color scale: Ozone concentration, ppm (NAAQS, max 8-hr avg. ≤ 0.075)
- Red indicates exceedance of ozone NAAQS
- X-axis: Peak daily load, GW, synchronized across NYISO, PJM and NE-ISO
- Y-axis: NOx emissions, tons/day

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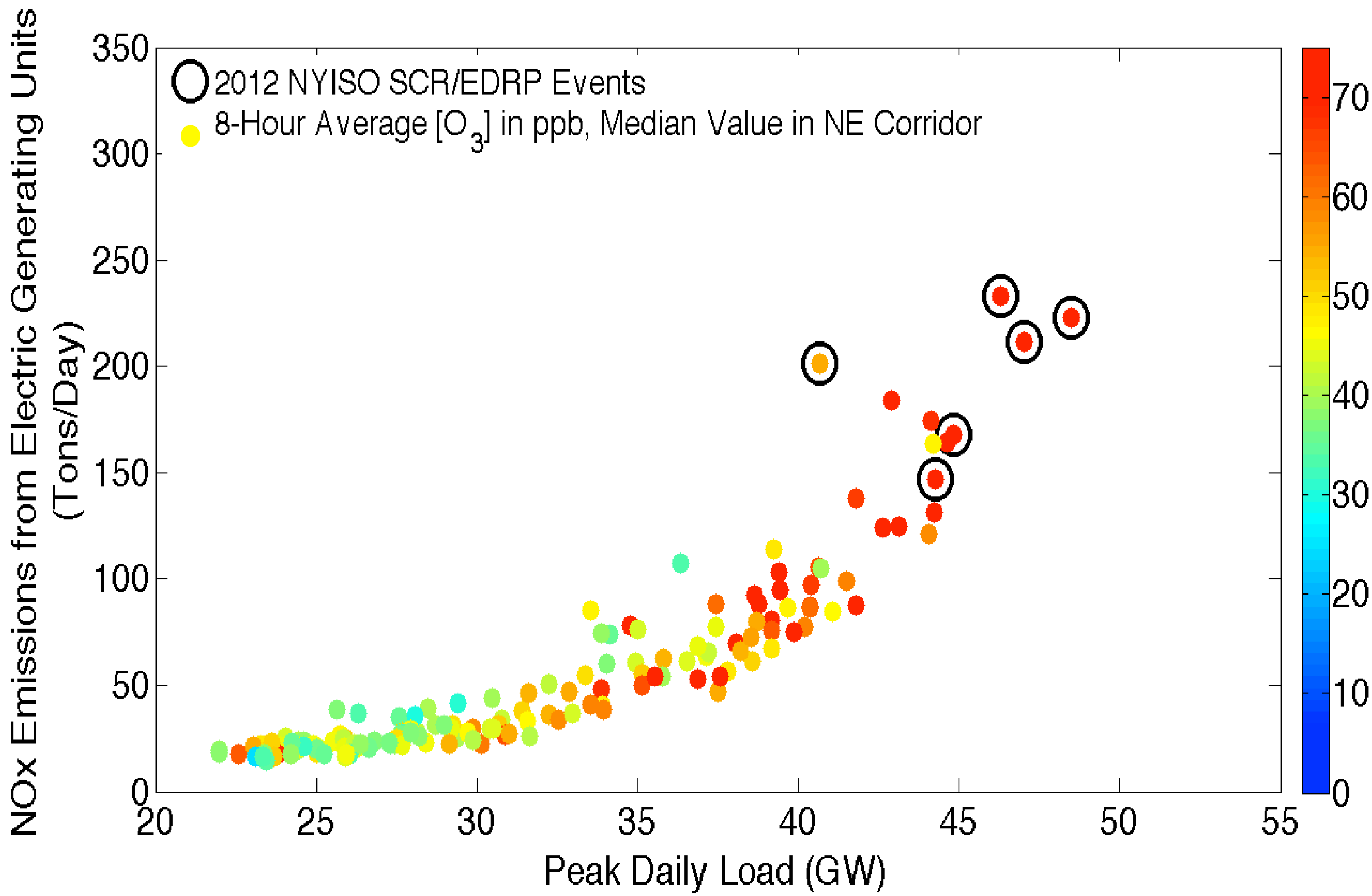
May 1 – September 30, 2012



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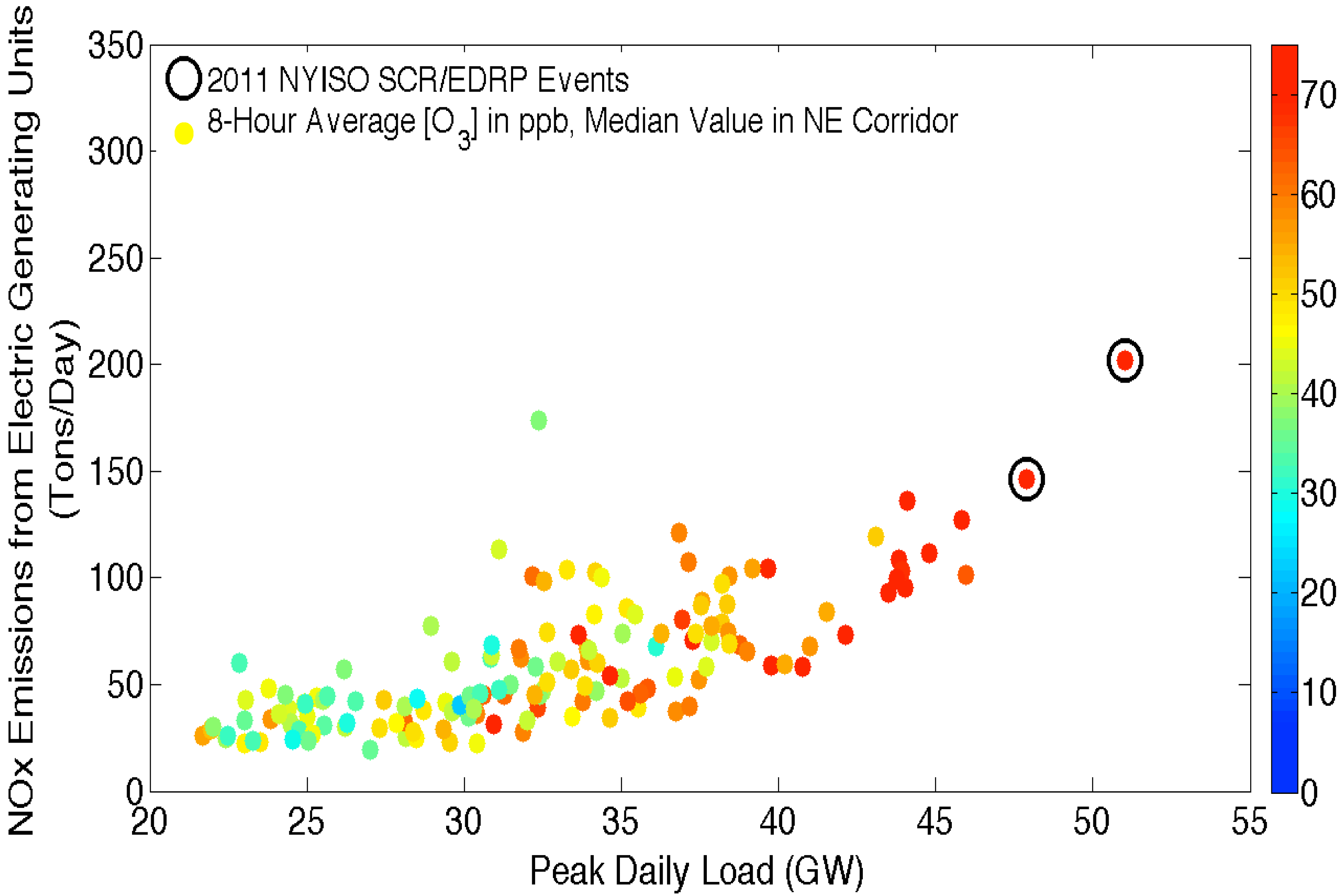
May 1 – September 30, 2011



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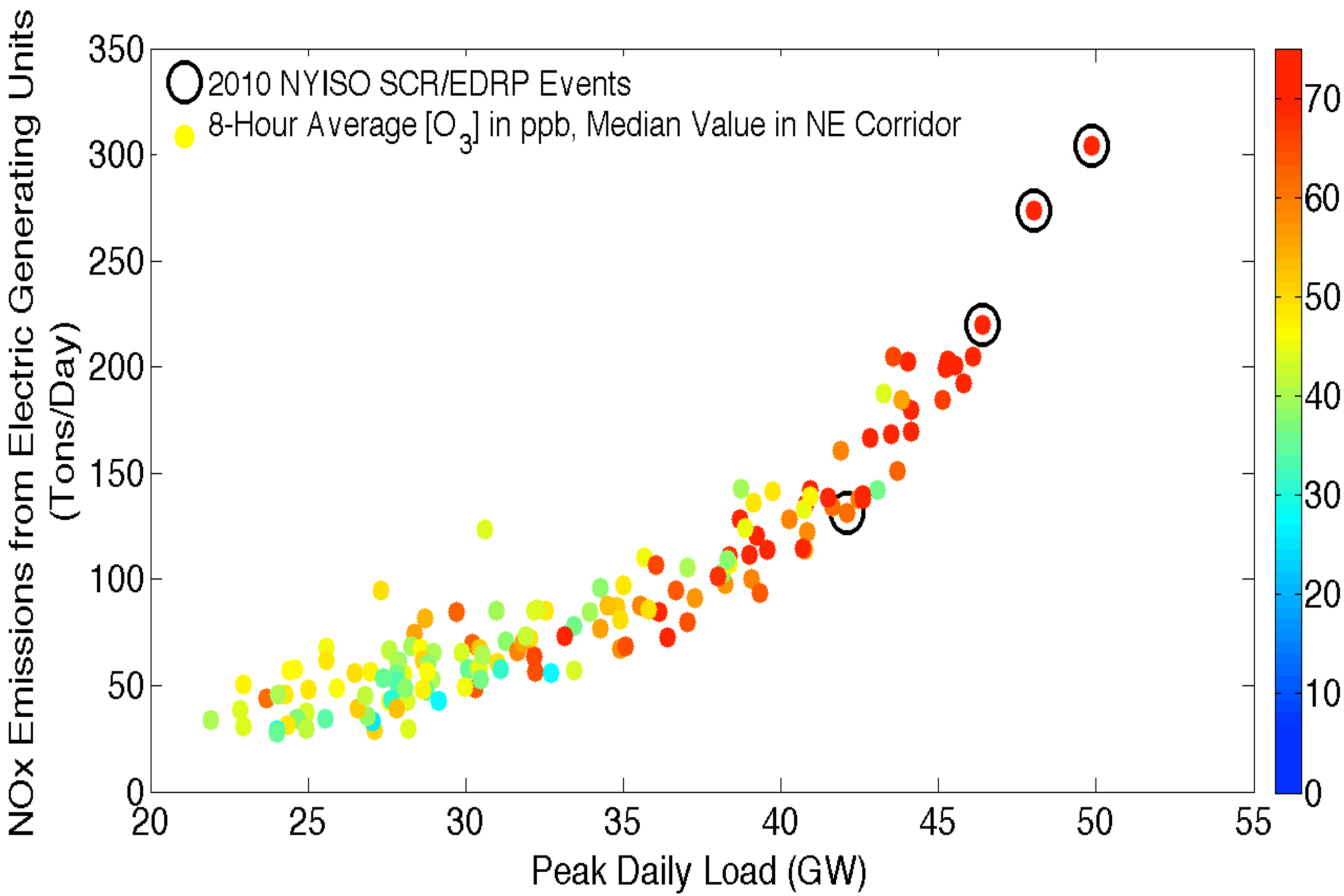
May 1 – September 30, 2010



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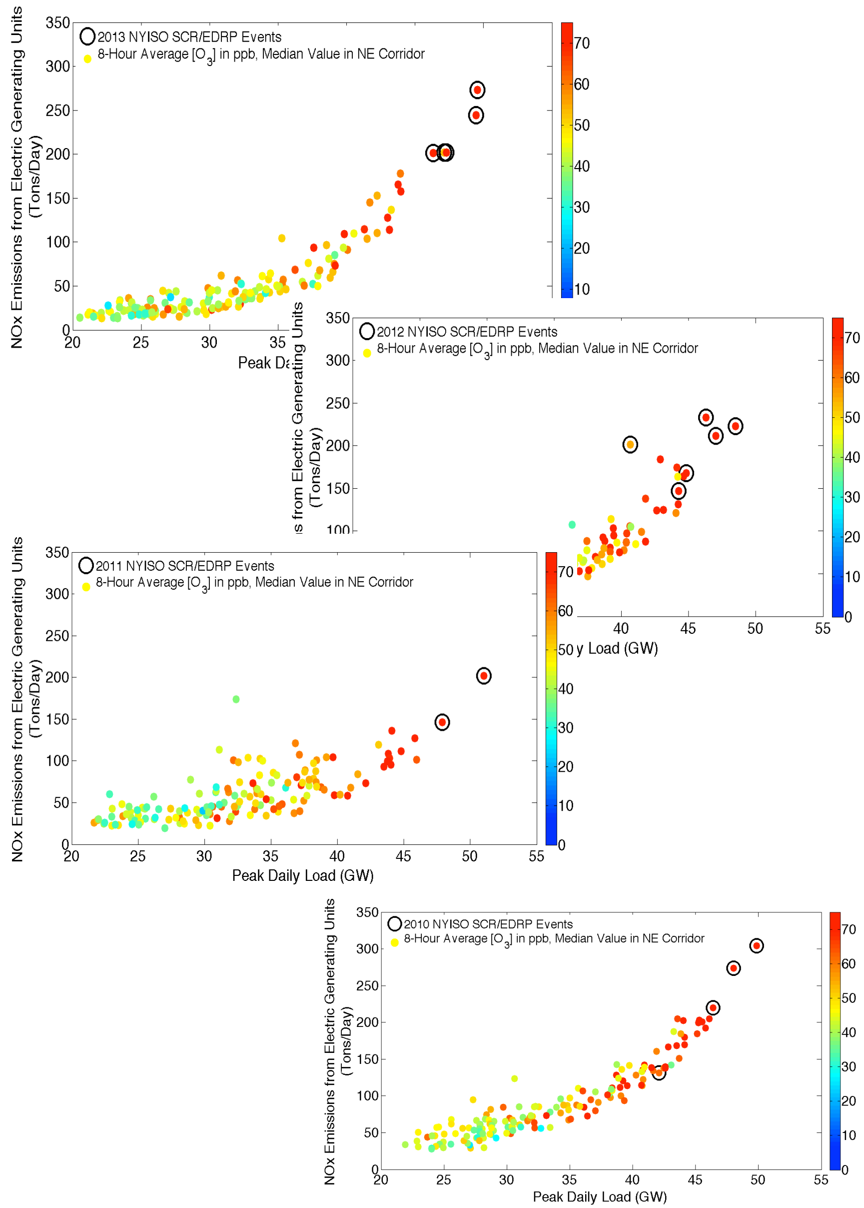
Observations

- In the Corridor region, the highest peak loads always correspond to the ozone concentration exceeding the NAAQS.
- NOx emissions occur when the atmospheric condition is most conducive to ozone formation, and contribute to potential ozone exceedance.
- NOx emissions, regardless of sectors, are most damaging during those periods.
- These also are the periods when NYISO EDRP/SCR events are most likely called.



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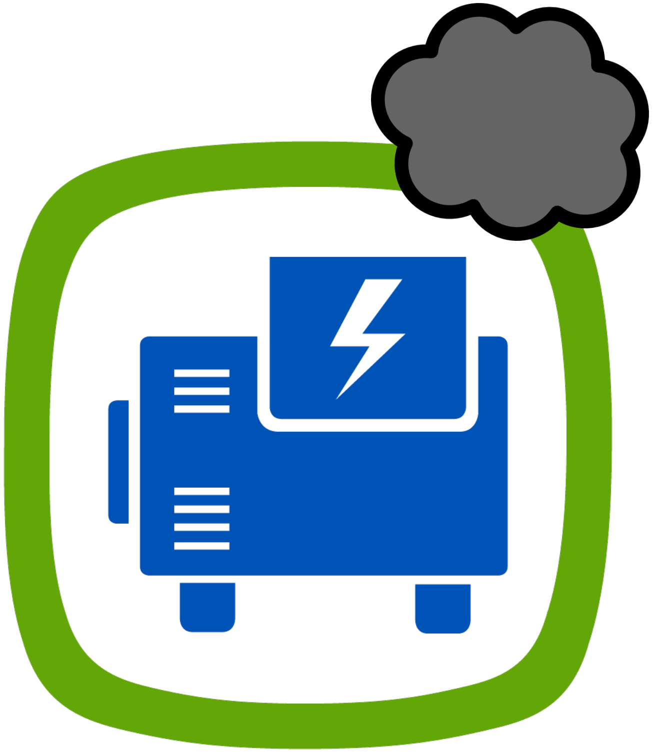
Demand Response:
Curtailment vs. Behind-the-Meter (BTM) generation



Almost all BTM generators are backup diesels

Emission Factors of Backup Diesel Generators

Unit: g/kWh

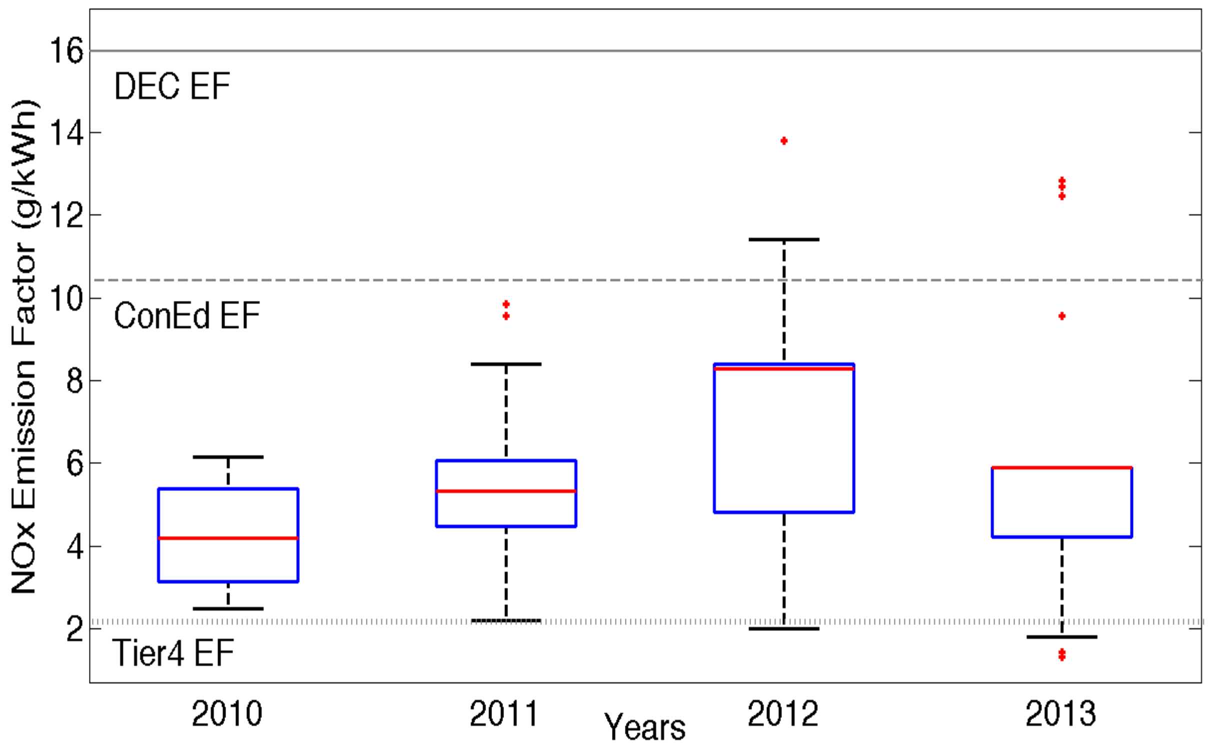
Tier4 EF	2.16 g/kW-hr (1.6 g/bhp-hr)
ConEd EF	10.63 g/kW-hr (7.9 g/bhp-hr)
DEC EF	16.00 g/kW-hr (11.9 g/bhp-hr)

Data Sources:
U.S. EPA. *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression Ignition*.
U.S. EPA. *Alternative Control Techniques Document: Stationary Diesel Engines*.
U.S. EPA. *Regulatory Impact Analysis for the Reconsideration of the Existing Stationary Compression Engines.*
NYC Energy Policy Task Force. *New York City Energy Policy: An Electricity Resource Roadmap.*
NYSDEC. *Overview of Part 222 Version MMXIII Stakeholder Meeting.*

- Best-Case Scenario
  - Assume all the engines meet Tire 4 emissions standards
  - Unrealistic at present, but shows the future emission control scenario.
- NYSDEC Estimation
  - BTM Generation Capacity in NYC: 1320 MW
  - DR Events Max Length of Time: 6 hours/day
  - Daily NOx Emissions from BTM Generators in NYC: 127 tons
  - 127 tons/1320 MW × 6 hours = 16 g/kWh

Comparing Emission Factors

NOx Emission Factors for Peaking Units in NYC and LI

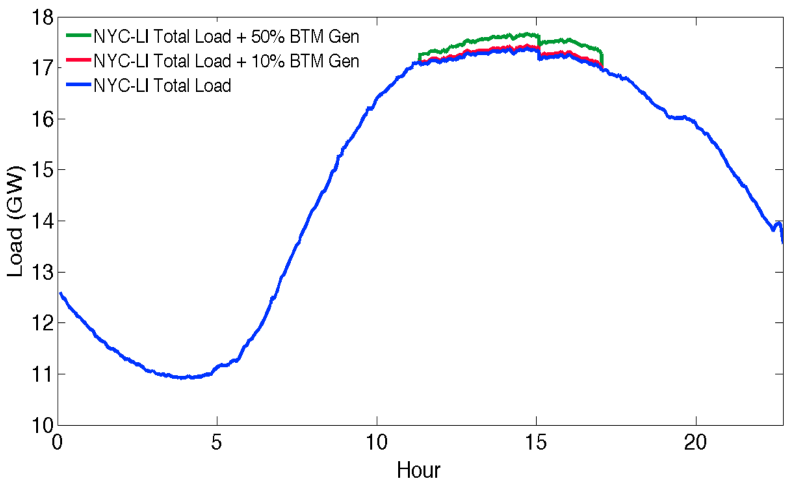


- Peaking units are identified based on annual operating hour restrictions to for CT to avoid LAER/BACT requirements for NOx emissions (≤ 66 hours in NYC).
- The EFs for BTM generators are similar to that for the highest emitting peaking units

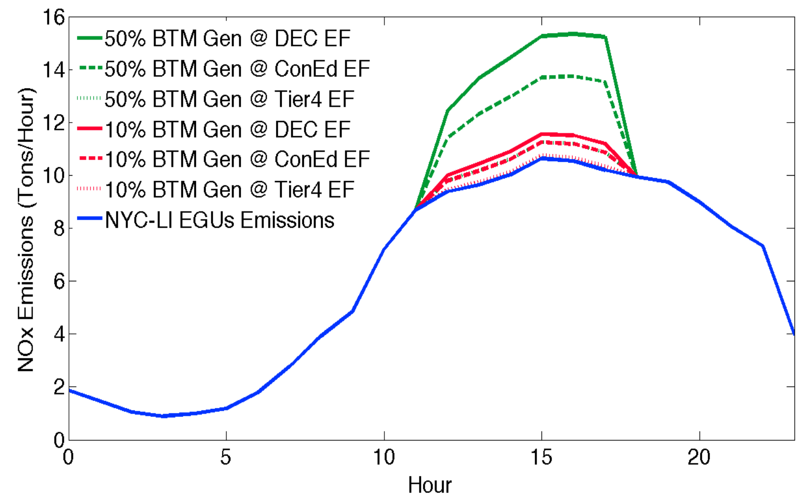
Zhang and Zhang (2015) ES&T, 49(3): 1260-1267

NOx contribution: July 22, 2011 – NYC + LI

- BTM Generation Meets ~1.5% of (NYC-LI Total Load + Load Reduction)



- BTM Generators Contribute ~15% of Total NOx Emissions (i.e. BTM Generators Emissions + NYC-LI EGUs Emissions) over the Day



During NYISO EDRP/SCR events called days from 2011 to 2013, NOx emissions from BTM generators in NYC/LI could vary from ~0.8 (May 29, 2012) to ~26 (July 22, 2011) tons/day, depending on the number of hours called, assumed emission factors, and BTM generators participation.

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The OTC States' Goal of NOx Emissions Reduction from HEDD Units

On July 22, 2011, 60.3 ton of NOx was emitted from BTM generators in NYS, assuming the electricity they generated met 50% of NYISO load reduction and using the NYSDEC NOx EF.

The amount exceeds New York State's goal of NOx emissions reduction associated with HEDD units on high electrical demand days during the ozone season, i.e. 50.80 ton, as specified in the OTC Memorandum of Understanding.

* All NYISO EDRP/SCR events are called on high electrical demand days during the ozone season, i.e. the BTM generators are the HEDD units of concern.

State	NOx (tons per day)	Percent Reduction from HEDD Units
CT	11.7	25%
DE	7.3	20%
MD	23.5	32%
NJ	19.8	28%
NY	50.8	27%
PA	21.8	32%
Total	134.9	

Data Source: Ozone Transport Commission. Memorandum of Understanding Among the States of the Ozone Transport Commission Concerning the Incorporation of High Electrical Demand Day Emission Reduction Strategies into Ozone Attainment State Implementation Plan

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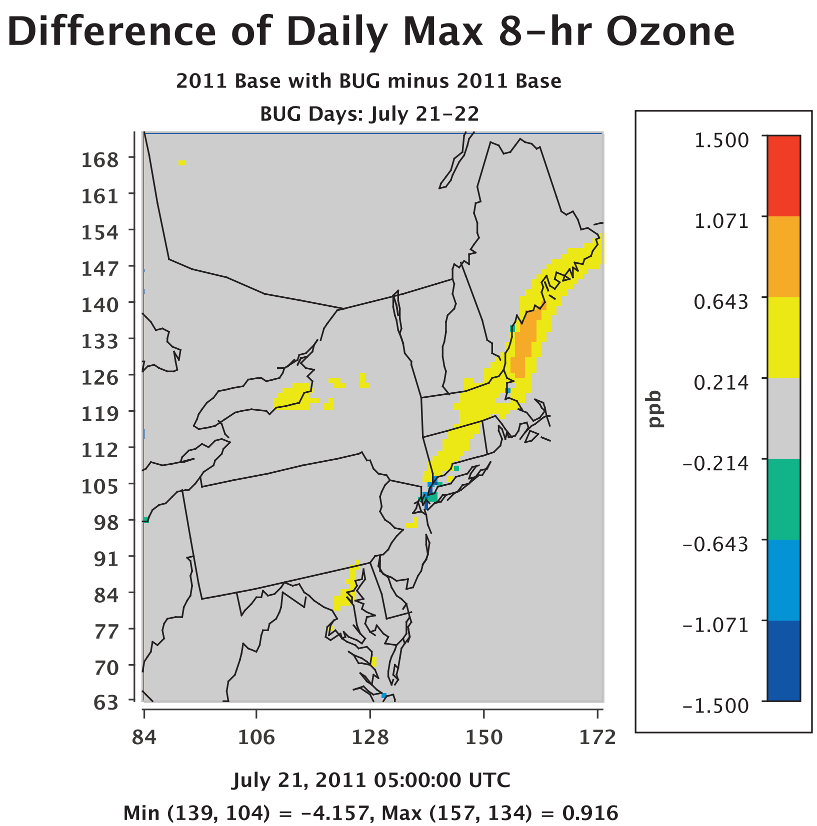
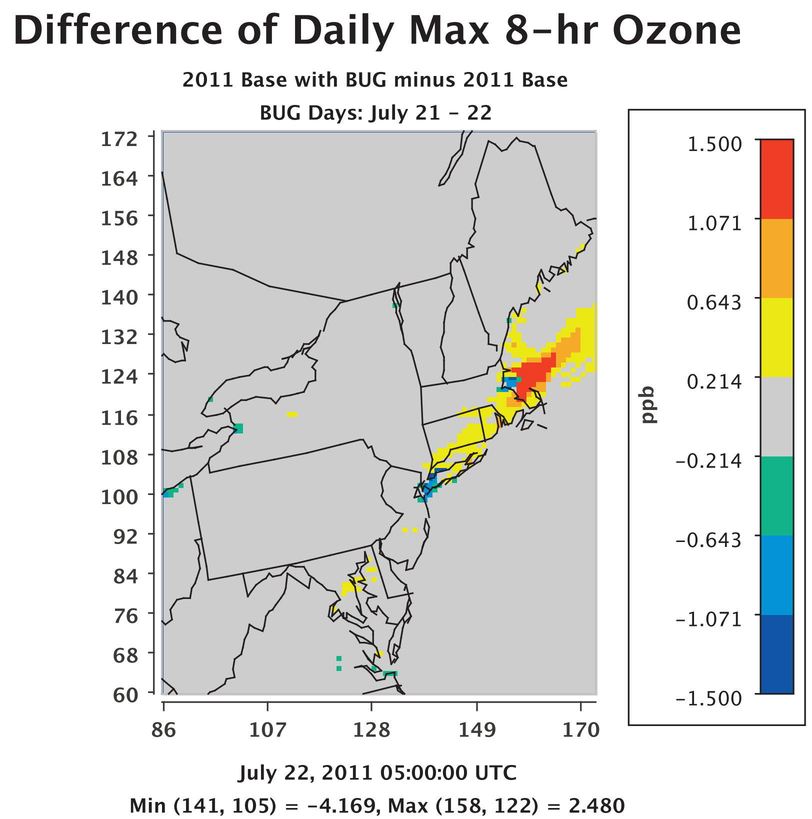
OTC Workgroup Modeling Results

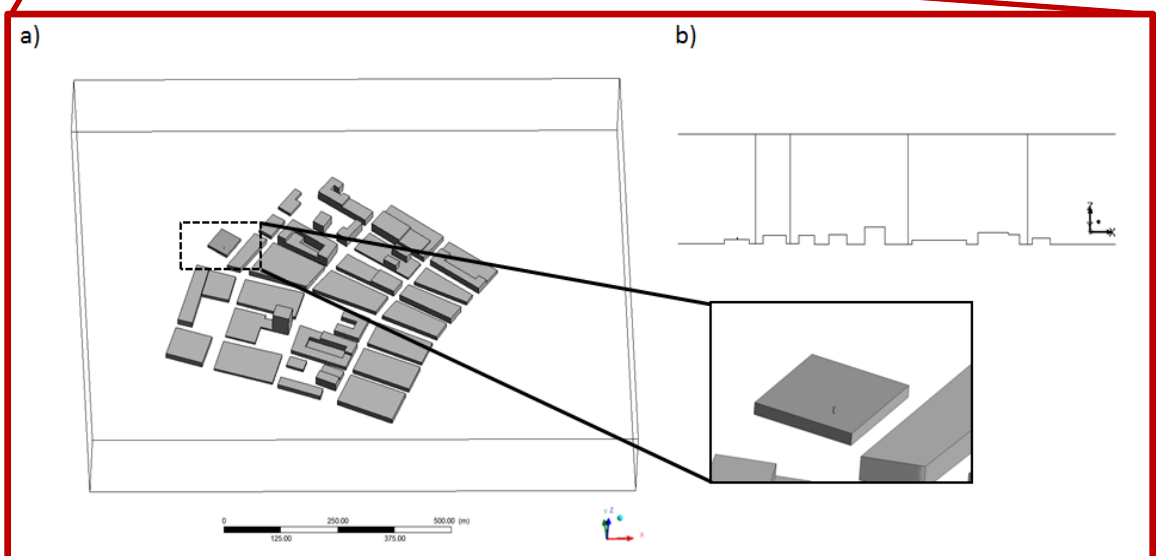




Healy et al. EM, March 2016

Diesel backup diesel generators

1200x1000x150m domain in NYC
4.5 million elements

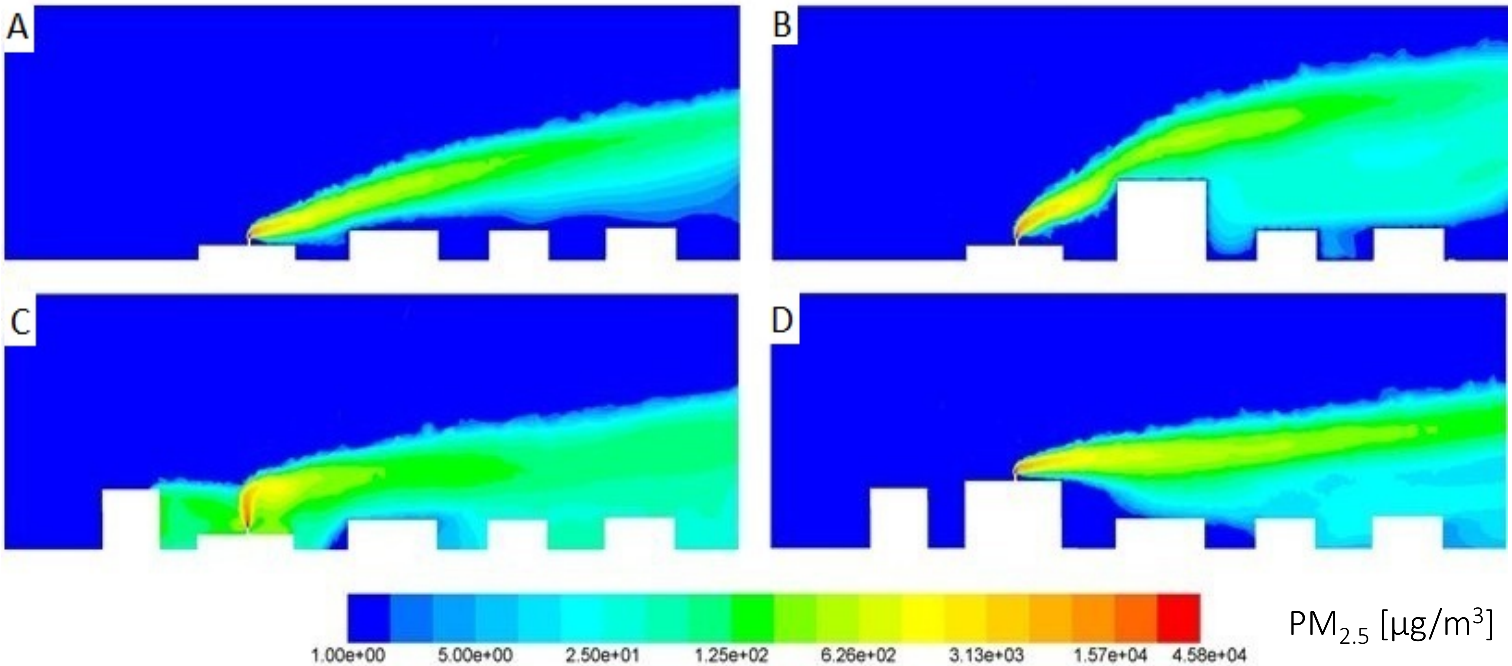


Stack Parameters

Exhaust velocity	15 m/s
Exhaust temperature	650 K
Stack Height	3.1m from rooftop
Stack Inside Diameter	0.77 m
NOx Emission	10.6 g/kWh
$PM_{2.5}$ Emission	0.5 g/kWh
Emission Standard	Mix of Tier 1,2 and Pre-Tier
Stability	Unstable, neutral, stable
Building Configuration	4 cases shown in Fig. 8

Tong and Zhang (2015)

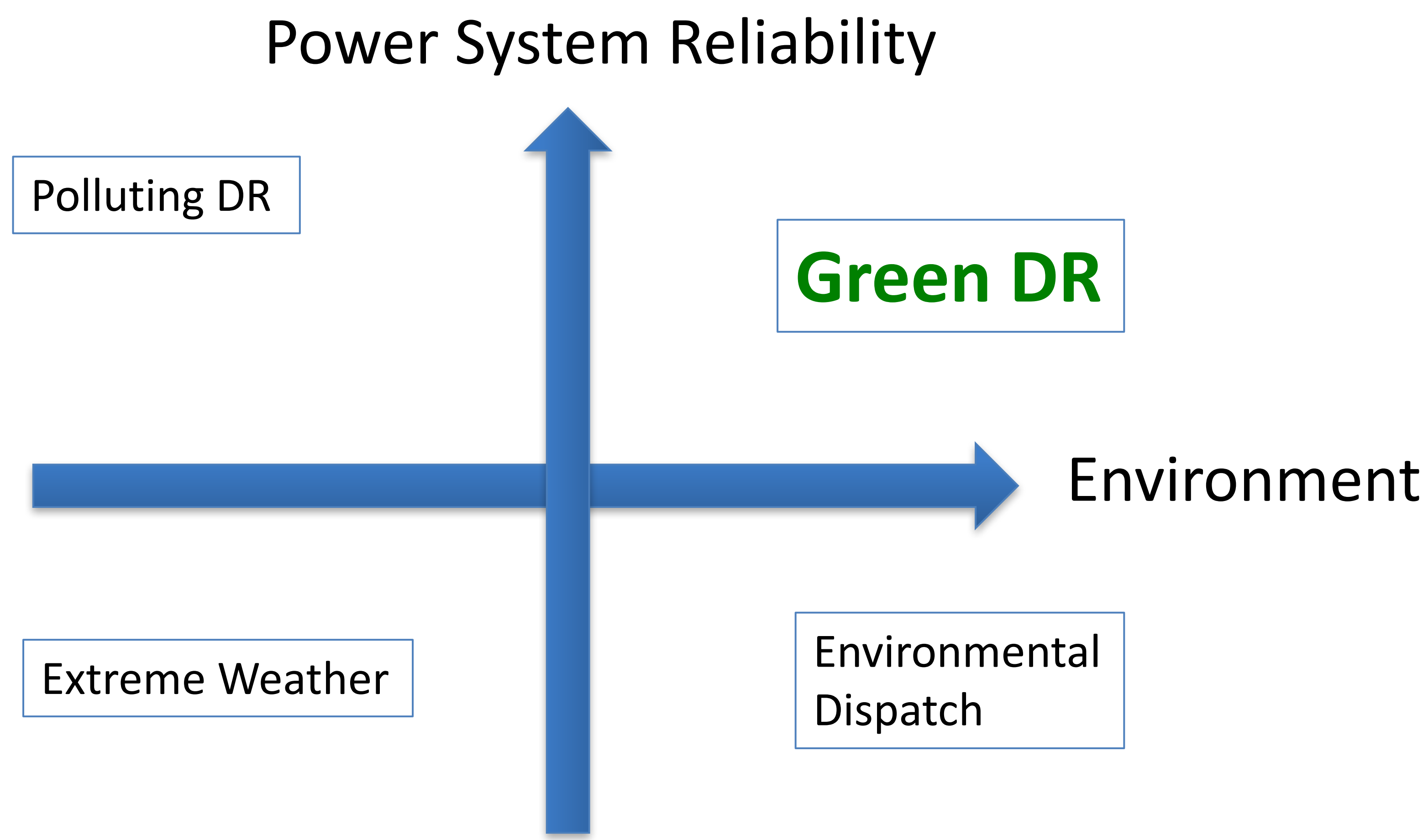
Siting matters!



- The particular boundary condition in this simulations is determined based on a particular hour when NYSIO emergency DR program was called in summer, 2013.
- In case C, the plume is drawn downward and sideways, reducing the near-stack dispersion and leading to elevated concentration inside adjacent street canyon. The near-source $PM_{2.5}$ concentration could well exceed 100 µg m^{-3} even under unstable atmospheric conditions.

Tong and Zhang (2015)

Green DR



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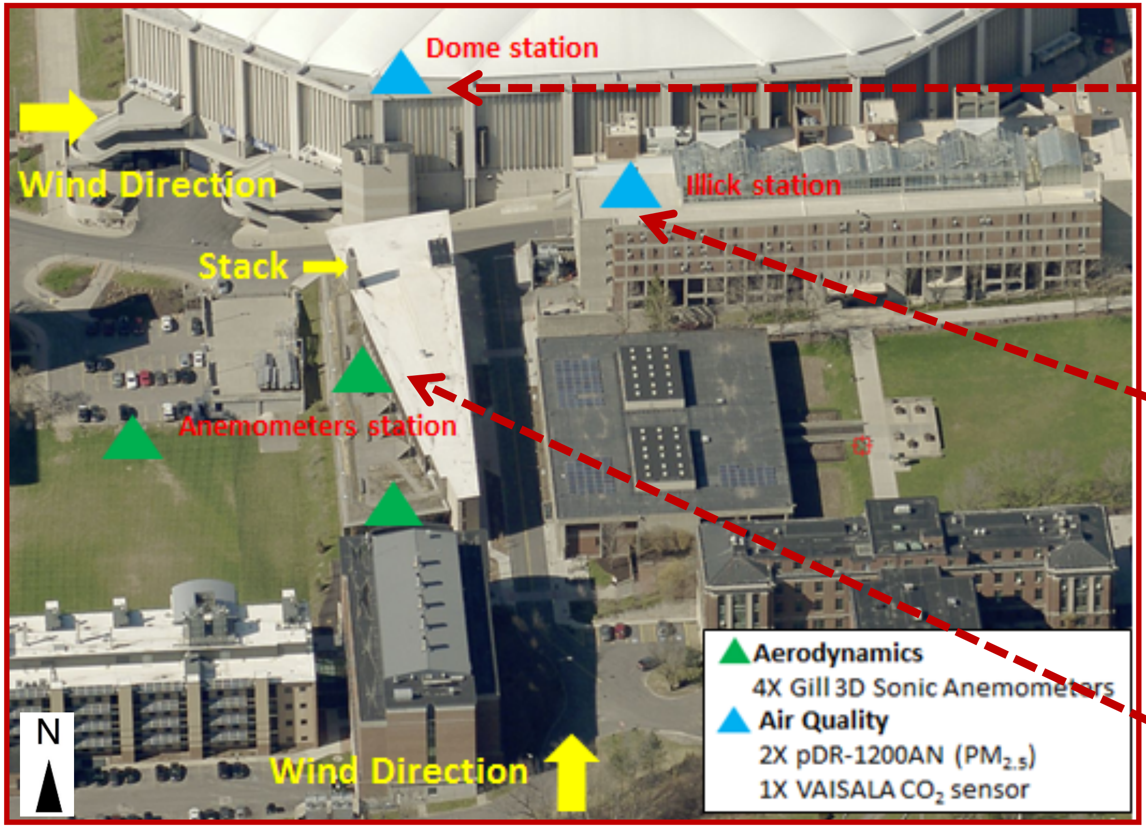
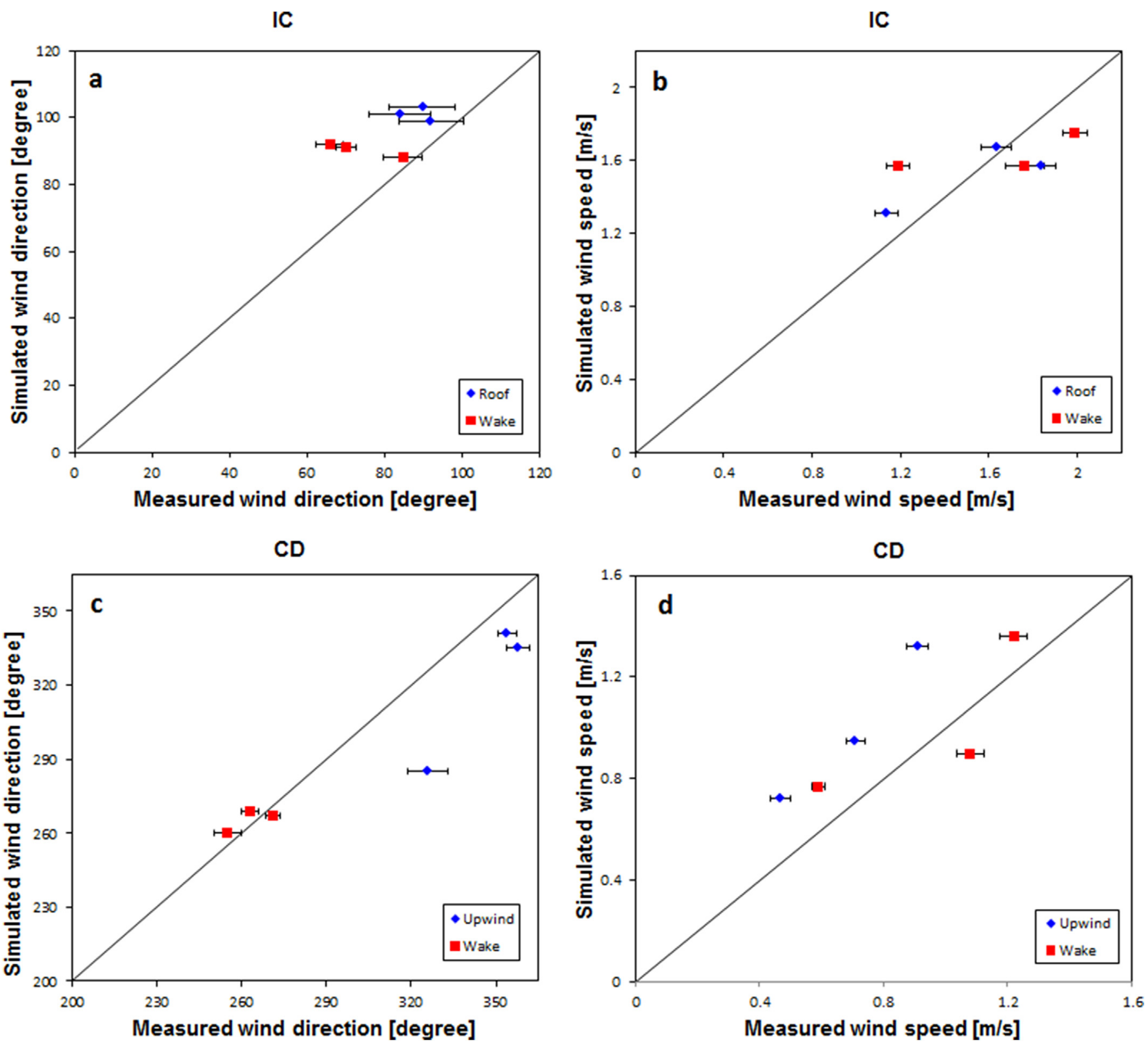
Biomass CHP at SUNY-ESF



Two rooftop sampling stations were set up in the way that one can capture the plume while the other one serves as the background in comparison depending on the wind direction.

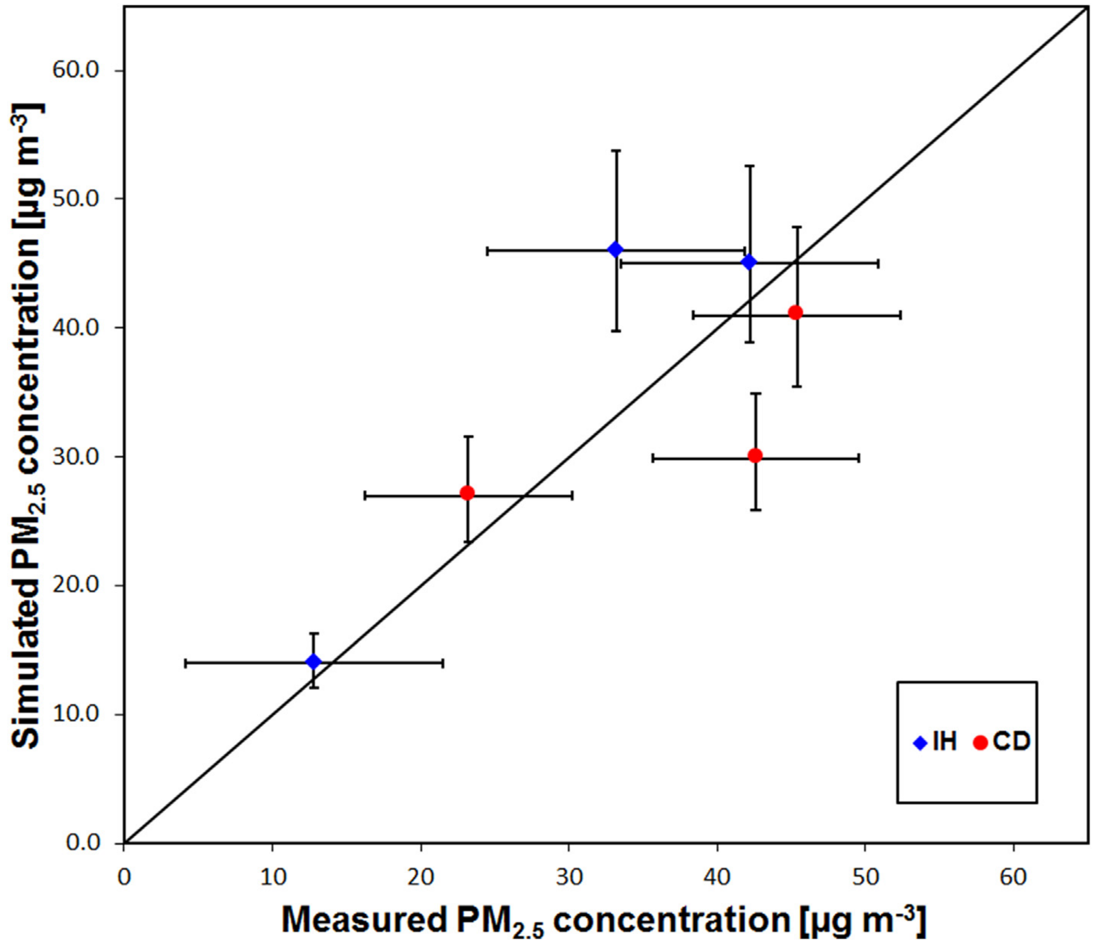
Tong et al. (2017)

Measured vs. predicted wind speed and direction



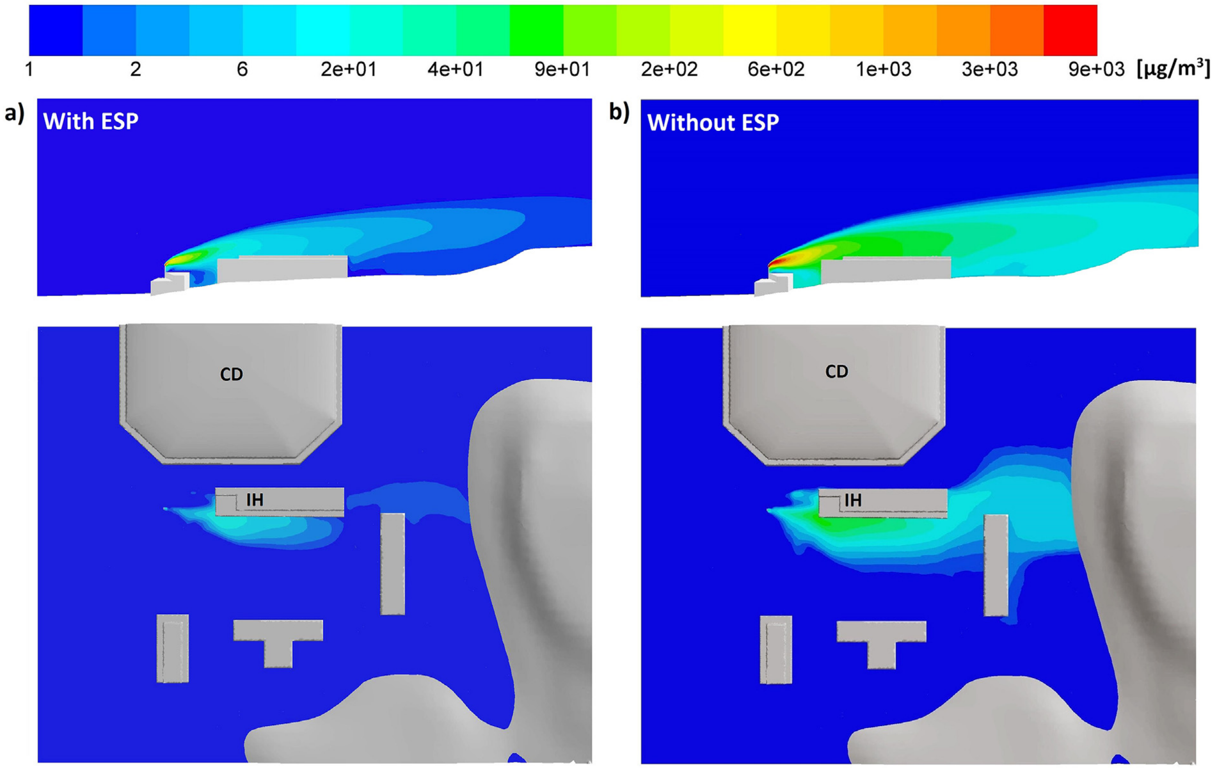
Tong et al. (2017)

Measured vs. predicted $PM_{2.5}$ concentrations



Tong et al. (2017)

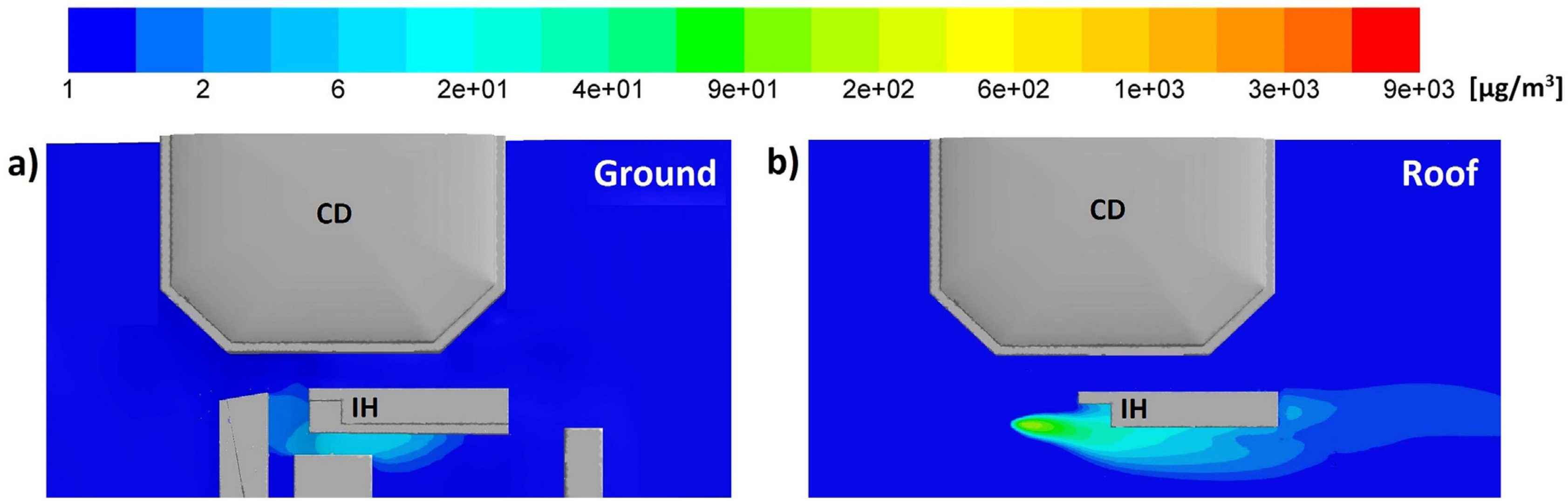
Sensitivity: With and Without ESP



- The emission factor in the absence of the ESP is derived based on the ESP efficiency measured in the stack test.
- The maximum near-ground concentration exceeds 30 µg m^{-3}. This is almost 7 times the concentration with ESP control.
- The concentration on the rooftop reached over 100 µg m^{-3}. This could be a serious health threat to people living inside the building as particles are able to transport indoor through windows or HVAC system.

Tong et al. (2017)

Ground-level vs. Rooftop-level



- The maximum concentration could exceed 35 mg m 3 at the rooftop and windward façade, even though the concentration at the ground level was nearly zero.
- DG permitting only considers ground-level concentrations.

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Main Messages

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