The City College of New York

CUNY The City University of New York

# "Transportation Electrification in Dense Urban Regions: Challenges and Opportunities: The New York City Case"


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Sandia National Laboratories Power Electronics and Energy Conversion Workshop

**ALBUQUERQUE, NM 87109 | AUGUST 2-3, 2023**

# Layout

- General Overview of the NY Power Grid
- NY Transportation Electrification Goals
- Sample Projects
- Education and Workforce Training Activities

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*New York, 1880's*

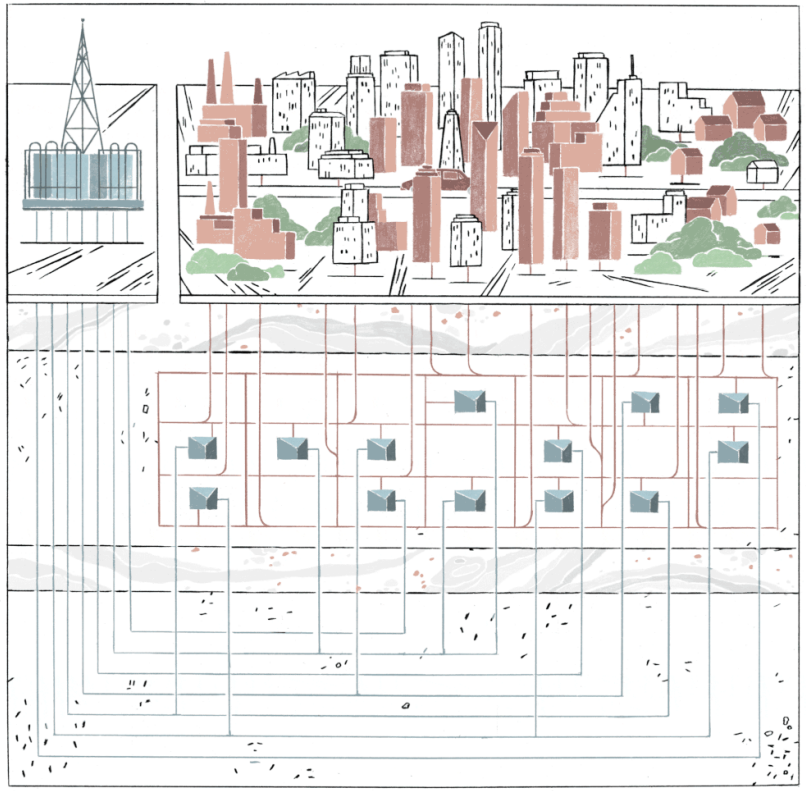
- Advances in electromagnetism
- Battery invented since 1800

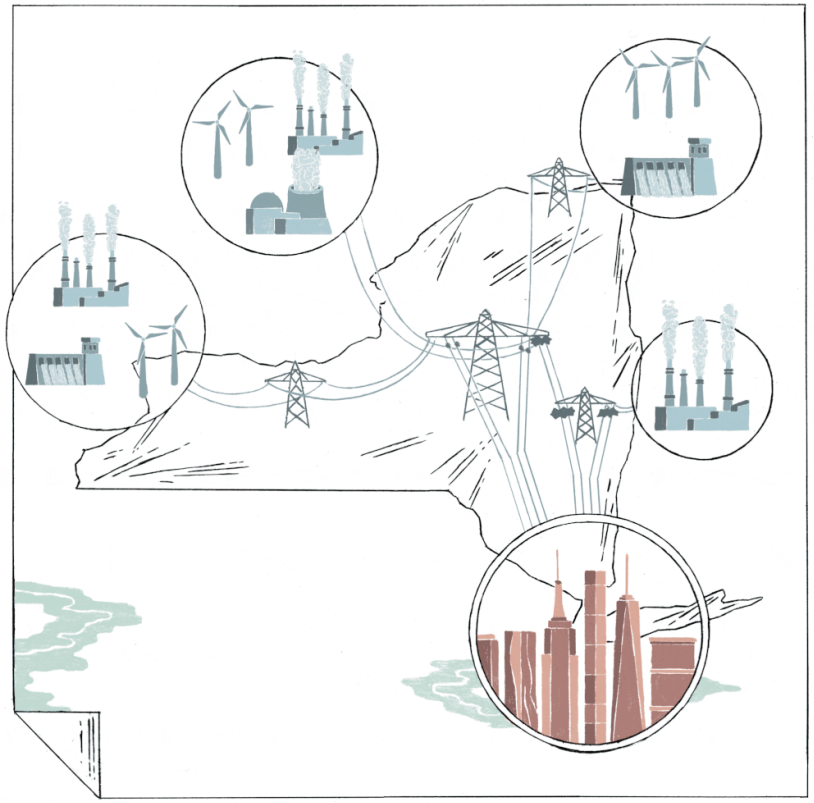
*However:*

- No electricity distribution yet
- Industrial revolution (machines and transportation are fuel based)
- Streetlights are gas based

# NY Power Grid

From Source to End Consumer!

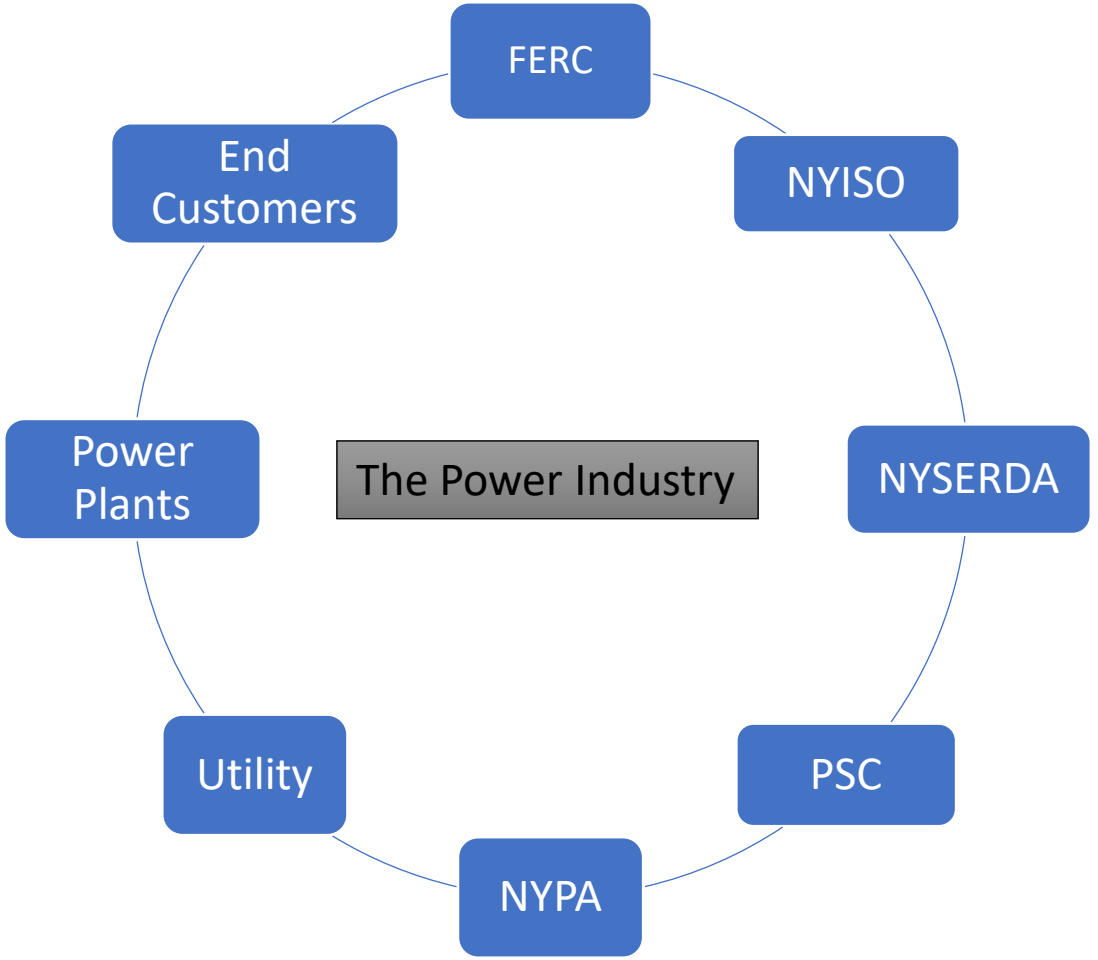




Credit: New York Times

# Key Players

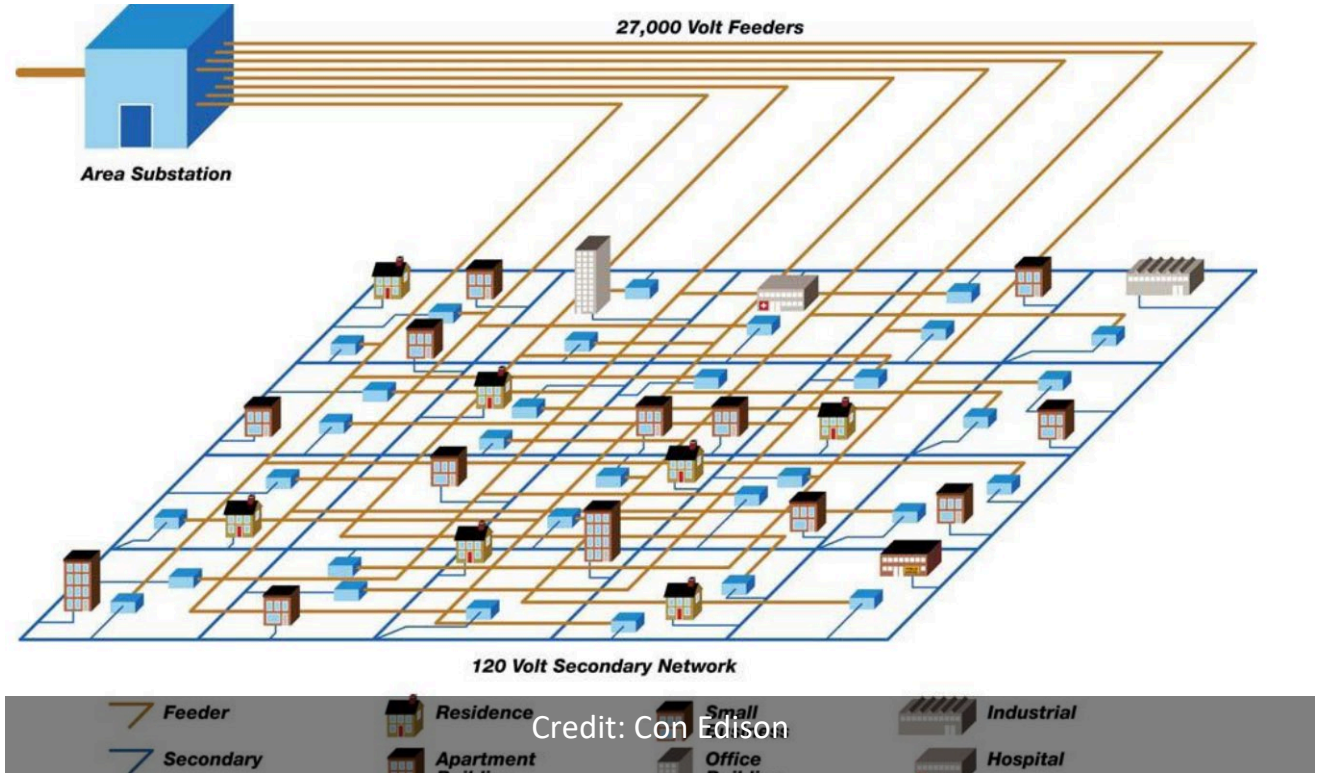
- The Federal Energy Regulatory Commission (FERC): A DOE agency that regulates transmission and sales of electricity between states
- New York Independent System Operator (NYISO): operates the NY's electricity system and competitive energy markets
- New York State Energy Research and Development Authority: driving force for renewable energy deployment and GHG emission reduction
- NY Public Service Commission (PSC): regulates the electric industries (can direct NYSERDA and utilities) and determines the electricity rate
- New York Power Authority (NYPA): public-benefit corporation that owns and operates generation and transmission facilities
- Utility Companies (Con Edison for NYC and Westchester): purchase and deliver electricity to end customers
- Power Plants: generate electricity



# How they work together..

- Investor/privately owned power plants, many of which are outside NYC, sell energy (over 95% of the electricity is sold a day or more ahead)
- NYISO manages the system
- FERC regulates the system
- The power is delivered to end customers through utilities and LSEs via 95,000 miles of underground distribution systems (largest underground system in the US)
- End customers buy power at a rate determined by the PSC

# Con Edison Network—Overview




Credit: Con Edison

- 9.5 million people served in NYC and Westchester
- 69 kV, 138 kV, and 345 kV transmission
- 27 kV for Brooklyn and Queens, 33 kV and 13 kV for Staten Island, and 13 kV for Manhattan, the Bronx, and Westchester County
- 50 area substations serving about 70 networks
- N-2 contingency design

1. M. Saleh, Y. Esa and A. Mohamed, "Impact of Communication Latency on the Bus Voltage of Centrally Controlled DC Microgrid during Islanding," *IEEE Transactions on Sustainable Energy*, Oct. 2019.
2. T. M. S. Ibrahim, T. T. De Rubira, A. Del Rosso, M. Patel, S. Guggilam and A. Mohamed, "Alternating Optimization Approach for Voltage-Secure Multi-Period Optimal Reactive Power Dispatch," in *IEEE Transactions on Power Systems*, Sept. 2022.

1. the imperative to decarbonize the grid by accommodating high penetration of renewable energy, in order to combat global warming;
   ***Solutions:*** visibility and smart controls (DERMS), short-term energy storage, cutting interconnection cost and queues
2. the growing load demand due to electrification (e.g., of transportation and heating sectors);
   ***Solutions:*** more load flexibility (non-wire solutions), incentive programs, eventually infrastructure upgrade
3. the need for increased resiliency in the face of low-frequency high-impact events, such as hurricanes and cyber attacks; and
   ***Solutions:*** microgrids, long-term energy storage, better understanding of critical infrastructure interdependencies
4. the need for trained workforce to cope with the emerging technologies.
   ***Solutions:*** updated curricula and degree/certificate programs, interdisciplinary education that bridges classical program boundaries (e.g., applications of AI in power grids)a

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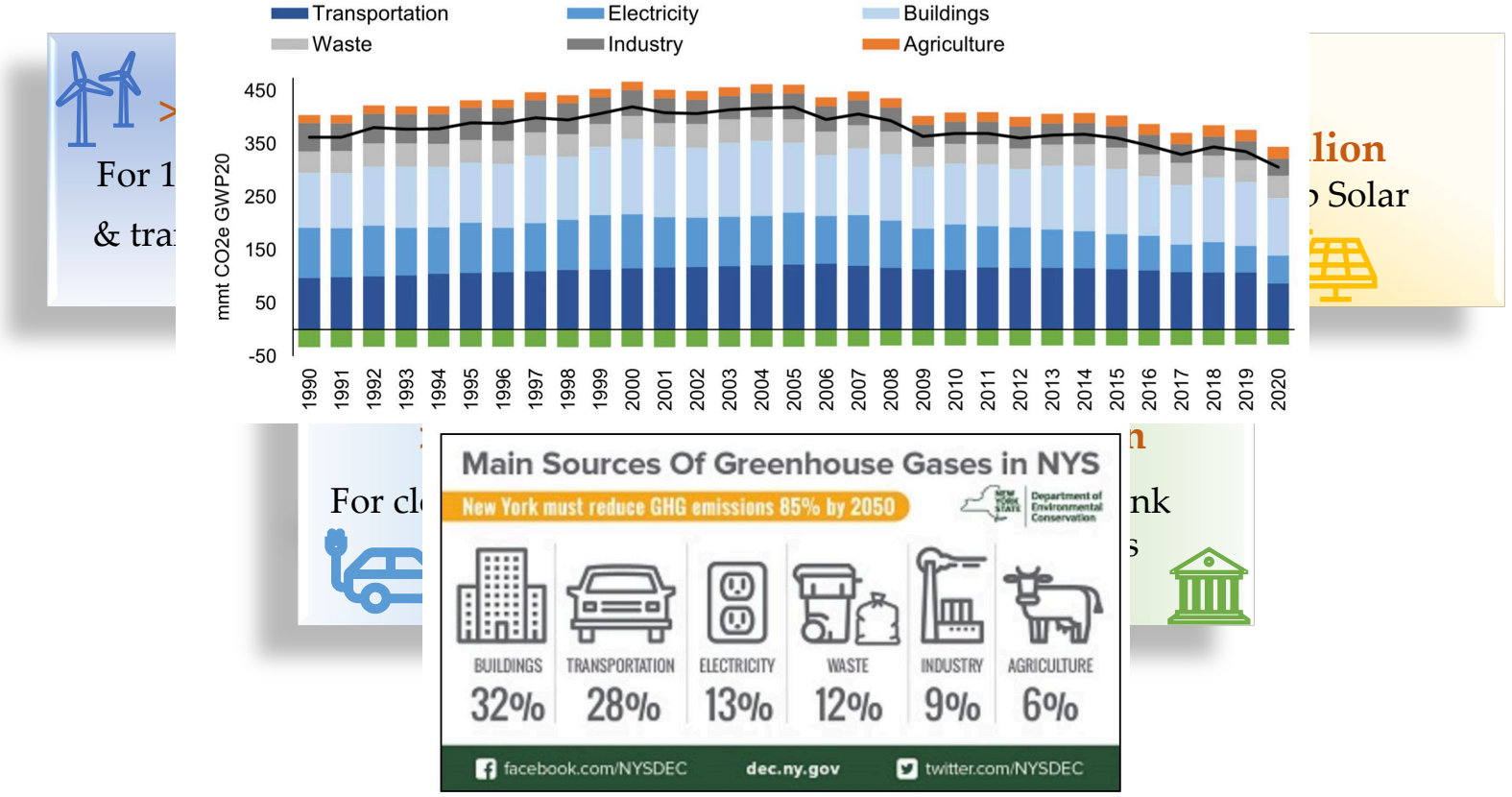
# Government Response– CLCPA (85% by 2050)

- In 2019, NYC passed the Climate Mobilization Act, a landmark set of local laws.
- Local Law 97 limits emissions from new and existing buildings over 25,000 square feet
- Local lows 92 and 94 require solar or green roofs for new building construction.
- NYC set a set of transportation electrification goals



# Transportation Electrification Goals



- By the end of the decade the city will need nearly 400,000 vehicles to switch to EVs, up from just 15,000 today.
  - ❑ To serve these EVs, the city will need over 40,000 publicly-accessible level 2 (L2) charger plugs and 6,000 fast charger plugs.
  - ❑ The number of EVs and public L2 chargers will need to quadruple, and the number of fast chargers must increase tenfold, by 2050.
- Electrification of bus and truck fleets
- Equip 20% of all spaces in municipal public parking lots and garages with level 2 chargers by 2025, increasing to 40% by 2030.
- Create a network of 1,000 curbside charge points across the five boroughs by 2025, increasing to 10,000 by 2030.

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# CUNY's Contribution

SGIL

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- Since 2017, the SGIL has been leading multiple projects that aim at analyzing the impacts of EV deployment and improving the energy efficiency of the NYC Subway System.
- These projects are sponsored by and in partnership with Consolidated Edison Inc., the New York City Transit (MTA), New York State Energy Research and Development Authority, NSF, and ESS vendors.
- Projects included multiple techno-financial feasibility studies, engineering design, and evaluation of pilot projects.

The City College of New York

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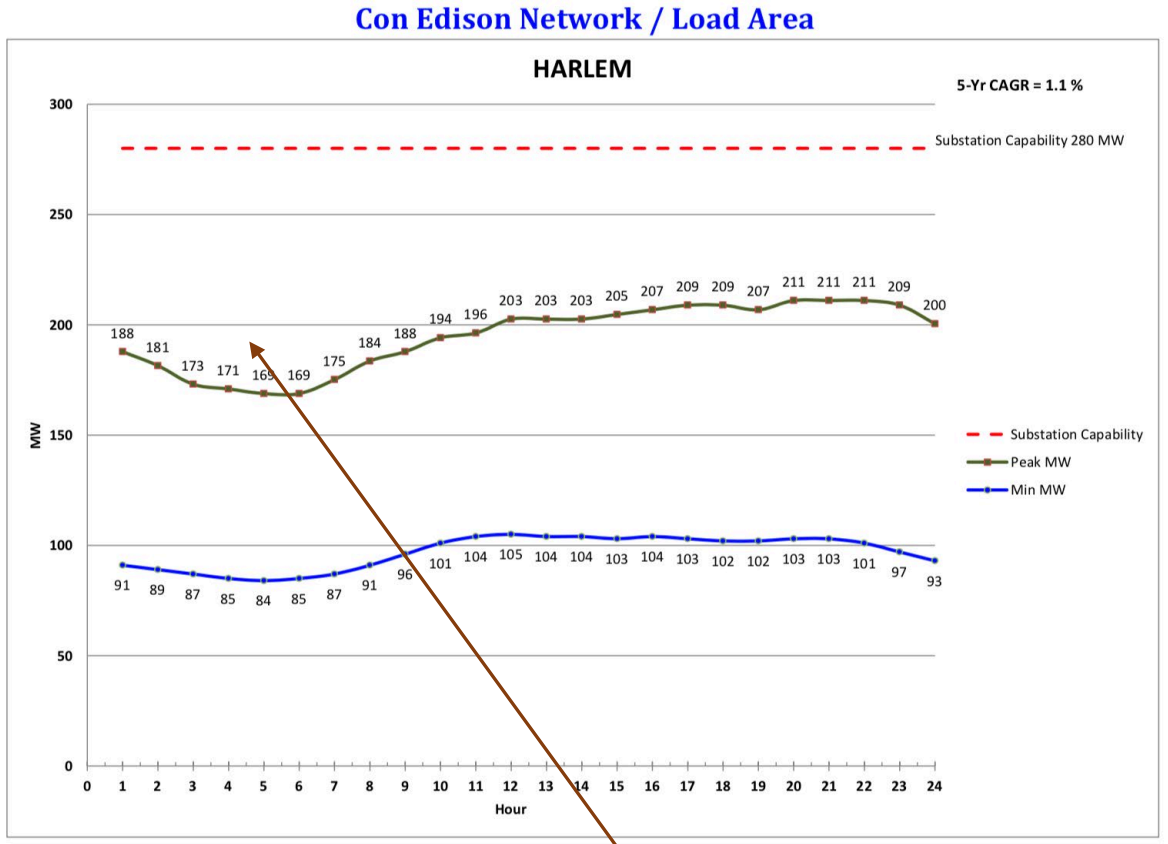
MTA New York City Transit

NSF

NEW YORK STATE OF OPPORTUNITY. NYSERDA

# Can the grid handle the charging load?

- Harlem is fed by a 280MW substation at 110th Street. The peak loading of this substation is about 76% (i.e., 212MW).
- There are 28 primary feeders (medium voltage) at 13.8kV.
- More than half of these feeders exceed 80% loading. Assuming that 23% of Harlem residents own cars, there will be 34,500 EVs.
- The demand to simultaneously charge half of this number is about 124MW, ~250% of the existing substation hosting capacity.

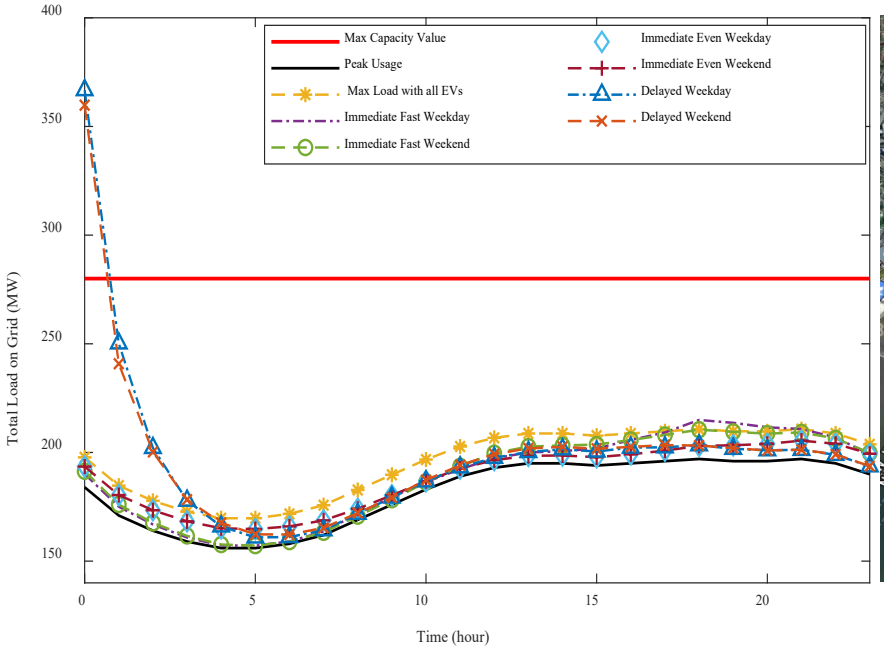



**Valley filling is not sufficient for some networks!**

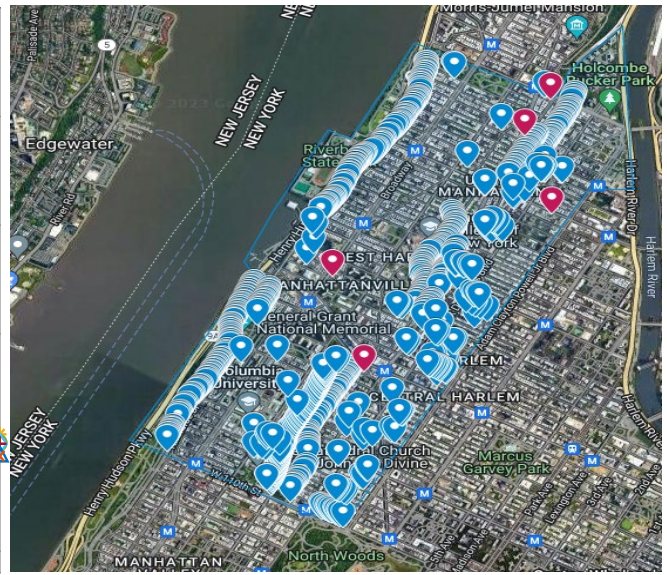
# Can the grid handle the charging load? A More detailed (and Optimistic) View…

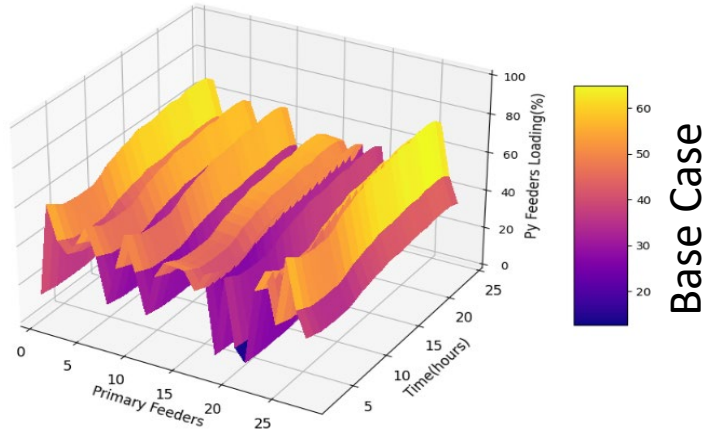
With restrictive/selective siting and scheduled charging, some networks can survive!
Primary feeders Okay, secondary feeders not so much!

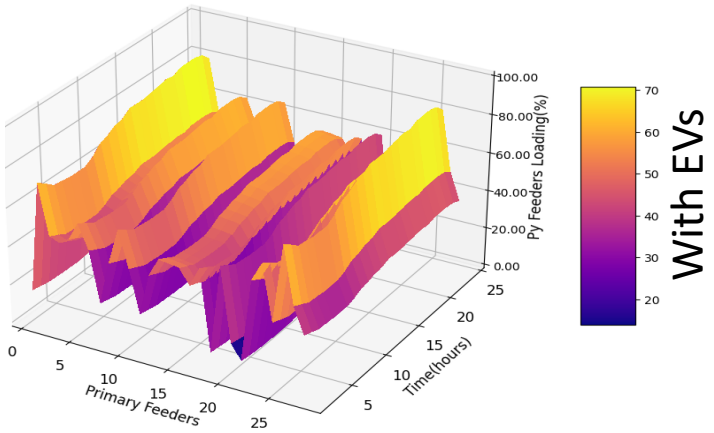
CONED Substation Loads




West Harlem Network

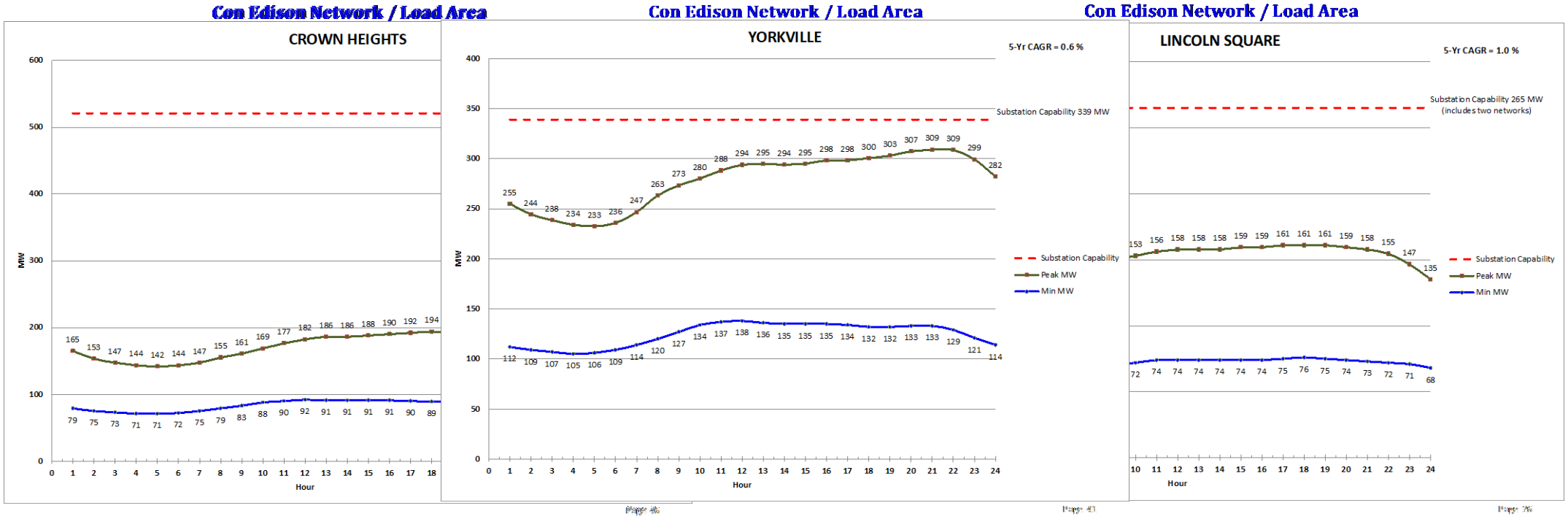



Feeder Loading

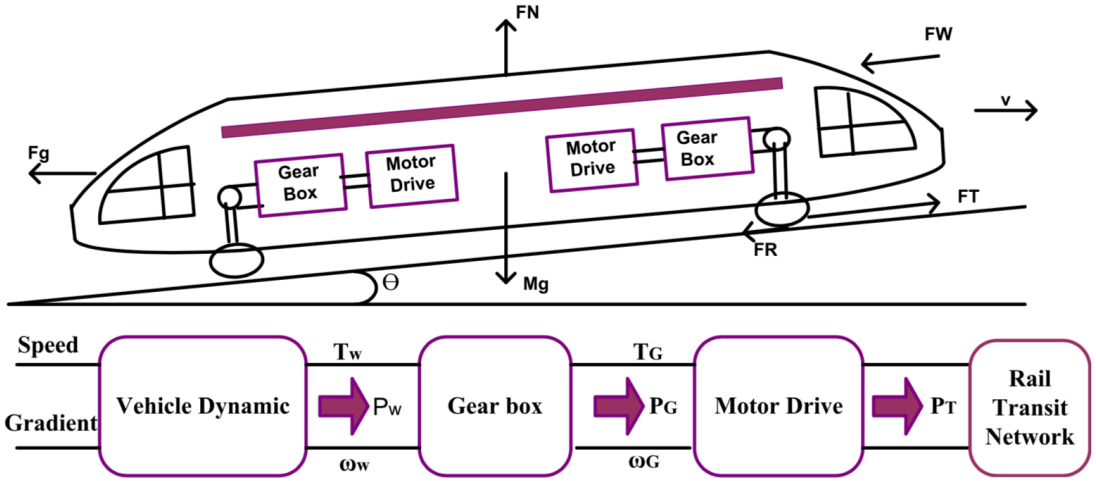
# How about other networks?



# The Subway


- The largest subway system (472 stations, $8.7B budget, ~6500 cars)
- About 2.4M riders daily
- 665 miles of revenue track
- A major energy consumer (about 1700 kWh annually)
- Wasted regenerative braking energy!

# Can we accurately model this system: Effect-Cause Model?




$$F_T - F_R - F_g - F_W = M_{Metro}\frac{dv}{dt}$$

$$F_R = f_R M_{Metro} g\cos\theta$$

$$F_g = M_{Metro} g\sin\theta$$

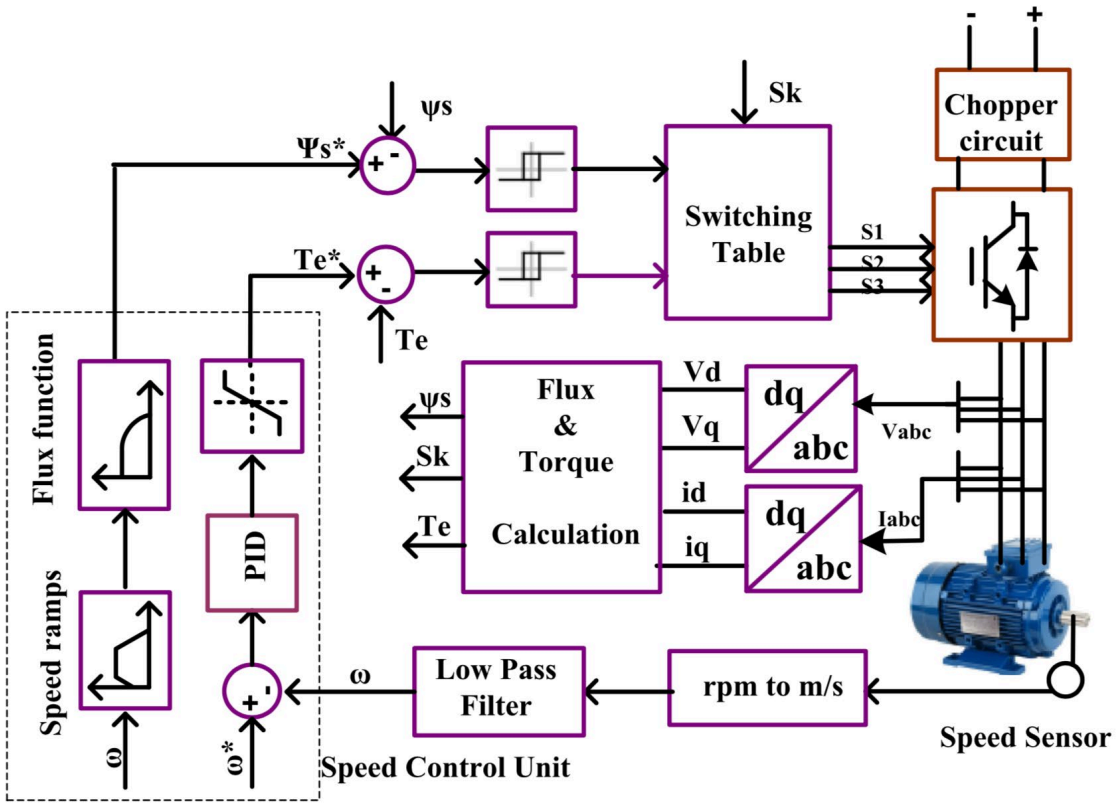
$$F_W = \frac{1}{2} C_w A \rho v^2$$

$$T_w = \frac{F_T \times r}{4 n_{cars}}$$

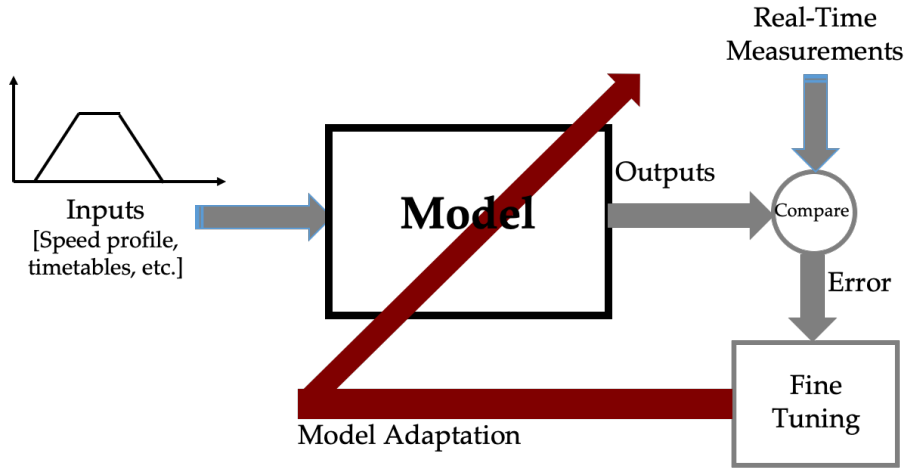
$$\omega_w = \frac{v}{r}$$

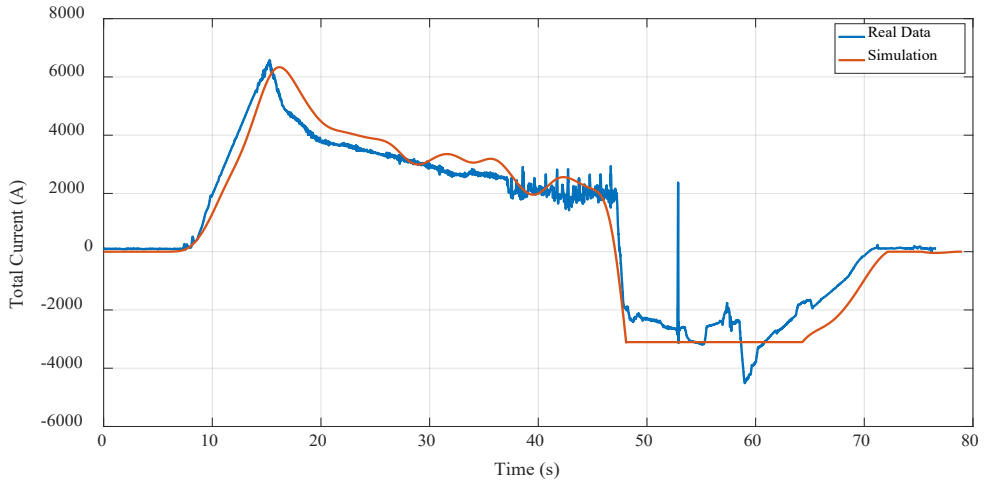
$$B = T_w(1-\eta_G)$$

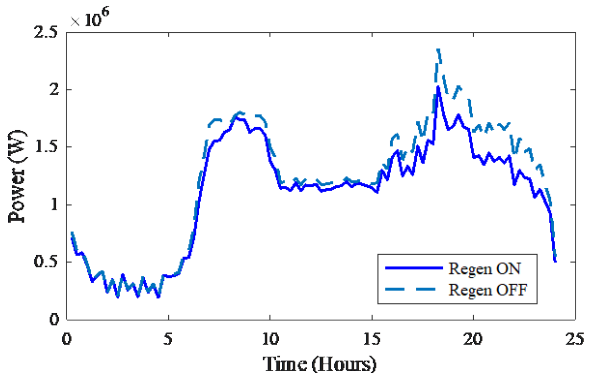
$$T_G = \frac{T_w}{\gamma_G} - \frac{B}{\gamma_G}$$

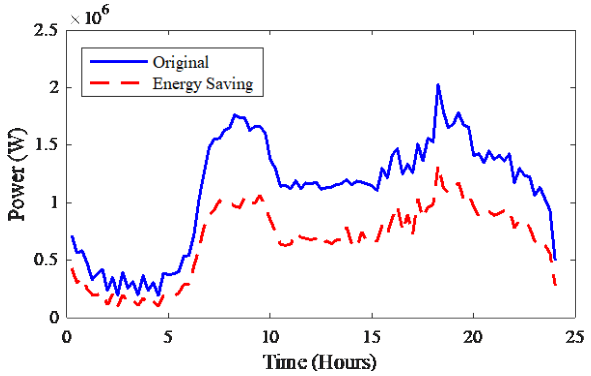


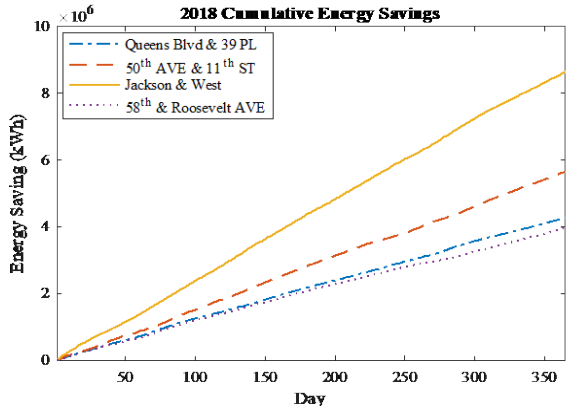
# Model-Guided Decision Making

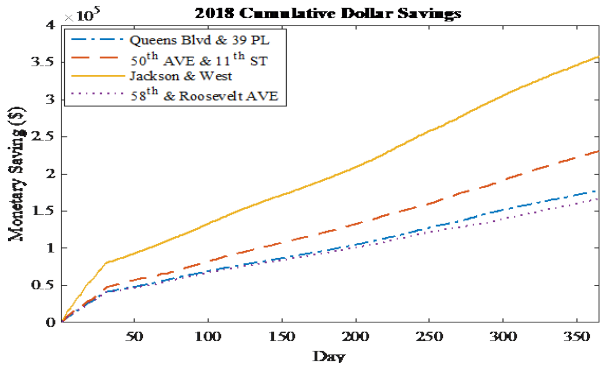


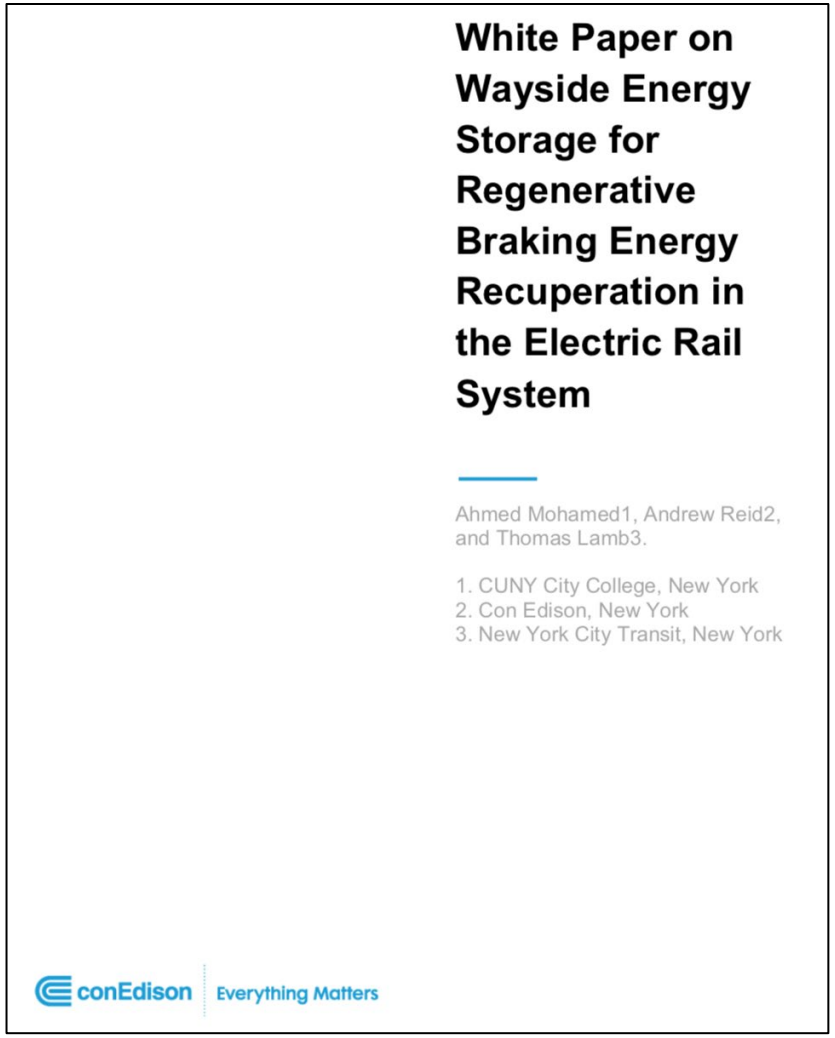




A. Mohamed et al, "Modeling of DC Electric Rail Transit Systems with Wayside Energy Storage," *IEEE Transactions on Vehicular Technology*, March 2019.

A. Mohamed et al, "Recuperation of Regenerative Braking Energy in Electric Rail Transit Systems," *IEEE Transactions on Intelligent Transportation Systems*, Jan. 2019.

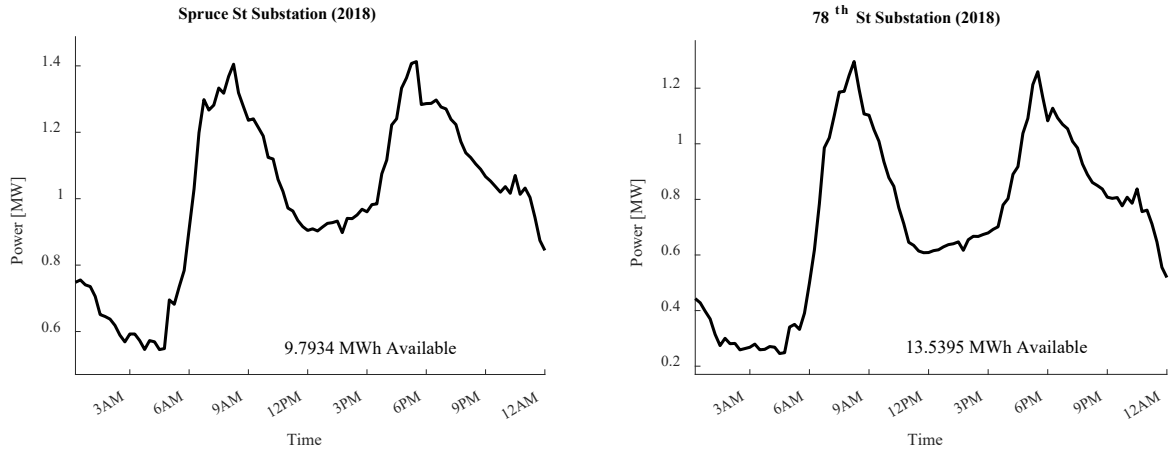
# Some Key Findings

- The SGIL study concluded that regenerative braking energy currently results in 8-9% saving.
- The SGIL study concluded that regenerative braking energy, if properly recuperated, can result in 35%+ energy savings.
- We explored how the regenerative energy within NYCT can be controlled to provide strategic smart grid services to ConEd's distribution grid, and what type of services can they reliably provide.
- Two ongoing pilot projects.



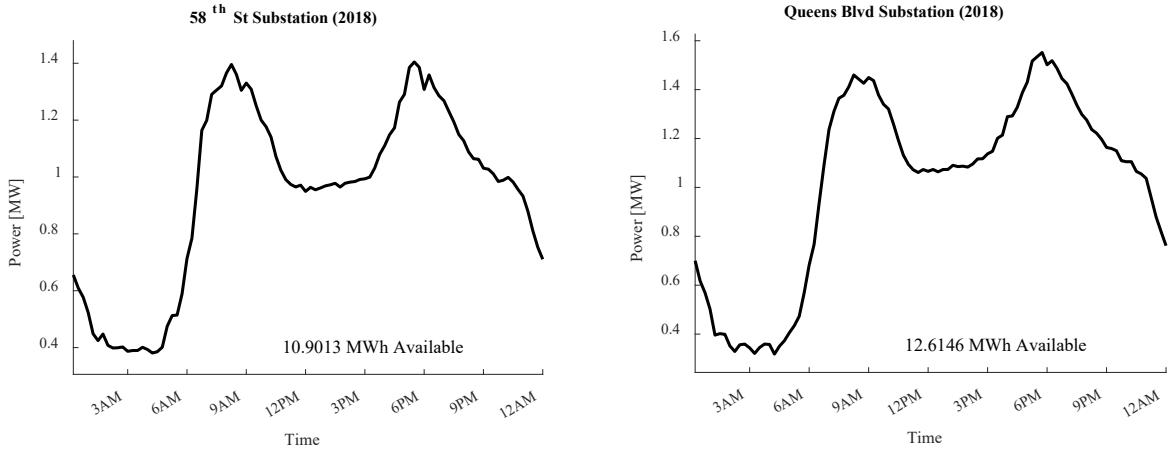

**A. Mohamed**, A. Reid (Con Edison), and T. Lamb (Metropolitan Transportation Authority), "White Paper on Wayside Energy Storage for Regenerative Braking Energy Recuperation in the Electric Rail System," published by Consolidated Edison, Inc., August 2018.

# Transportation/Energy Hubs









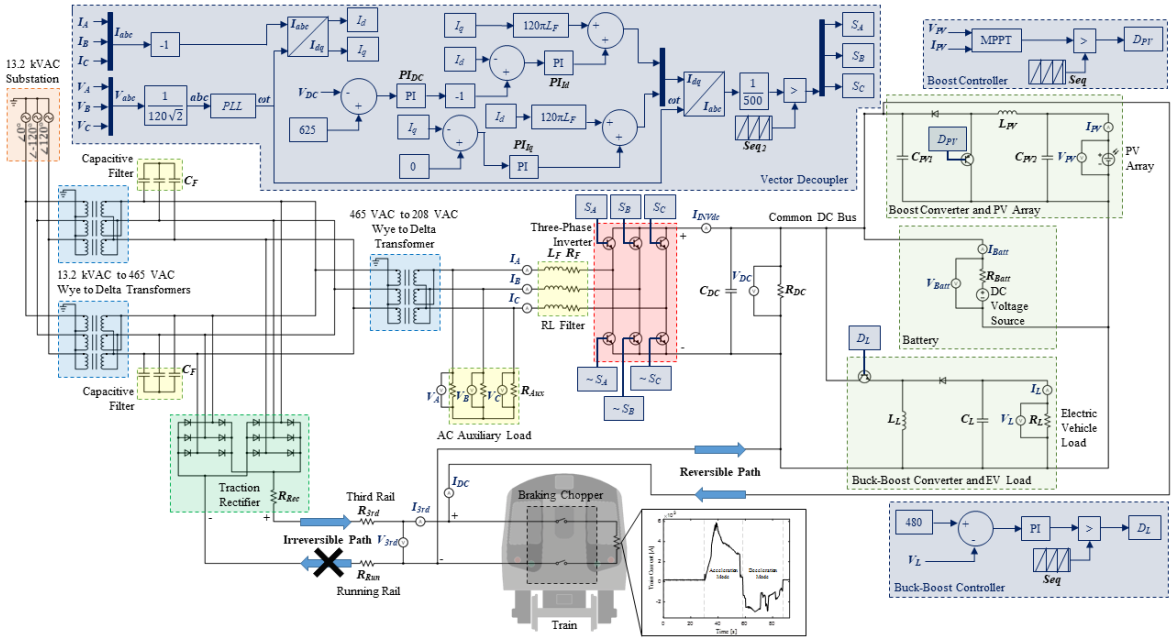





Williamsburg Subway and Bus Intersection

Rockefeller Center Subway and Bus Intersection

# Transportation/Energy Hub




A. Mohamed et al, "DC Energy Hubs for Integration of Community DERs, EVs, and Subway Systems," Sustainability 2022, 14, 1558. https://doi.org/10.3390/su14031558.

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# Education and Workforce Training Activities



- The CUNY City College has been a major pipeline for power engineers and technicians in the metropolitan area
- We work closely with the State and industry partners to develop new education and workforce training activates
- A new power lab will be commissioned in 2023/2024

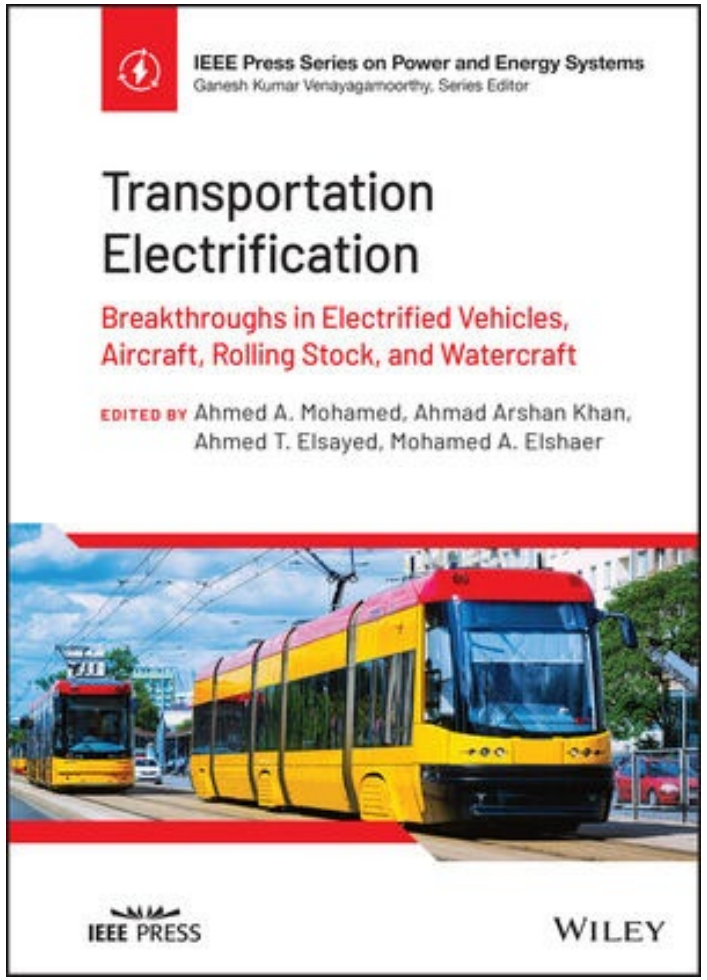
# The NAC Parking Lot Project

- 300 kW canopy solar
- 250 kWh/1MW kW BESS
- Electric Vehicle fast chargers
- The facility will be open for students and trainees
- Telemetering and controls are managed centrally at the new Power lab
- In addition to the NAC parking lot installation, the new power lab will include building-scale energy storage system and state-of-the-art training equipment


# Education and Workforce Training Activities

The Lab

More on Transportation Electrification!




Thank you

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