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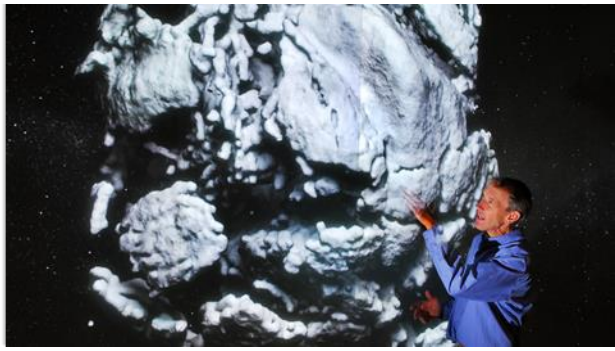

US Microgrids for Enhancing Resilience

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Topics

- About Sandia National Laboratories
- Defining Resilience
- Hurricane Sandy
- New Jersey Transit Microgrid
- City of Hoboken, NJ Microgrid

Where Is New Mexico?

- 5th largest state in the US
- Population: 2.1 million
- New Mexico is known for its beautiful landscape, rich culture, high tech industry, plentiful wind and solar resources

Resilience versus Reliability

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Separating reliability and resilience is important

- **Reliability is compulsory**
- **Reliability is related to rate recovery**
- **Adoption of resilience metrics will be easier if reliability definitions remain as-is**

Reliability	Resilience
High Probability, Low Consequence (SAIDI/SAIFI exclude storm data)	Low Probability, High Consequence
Not risk based	Risk Based, includes: Threat (you are resilient to something) System Vulnerability (~reliability) Consequence (beyond the system)
Operationally, You are reliable, or you are not [0 1]. Confidence is unspecified	Resilience is a continuum, confidence is specified
Focus is on the measuring impact to the system	Focus is on measuring impact to humans

Designing Microgrids for Resilience

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- Engage stakeholders
- **Establish a design basis** Define performance metrics
- Define system boundaries
- Collect system and operations info and data
- Generate feasible designs
  - **measure performance against the design basis**
  - improve the design
  - repeat

Superstorm Sandy

October, 2012

Impact of Superstorm Sandy

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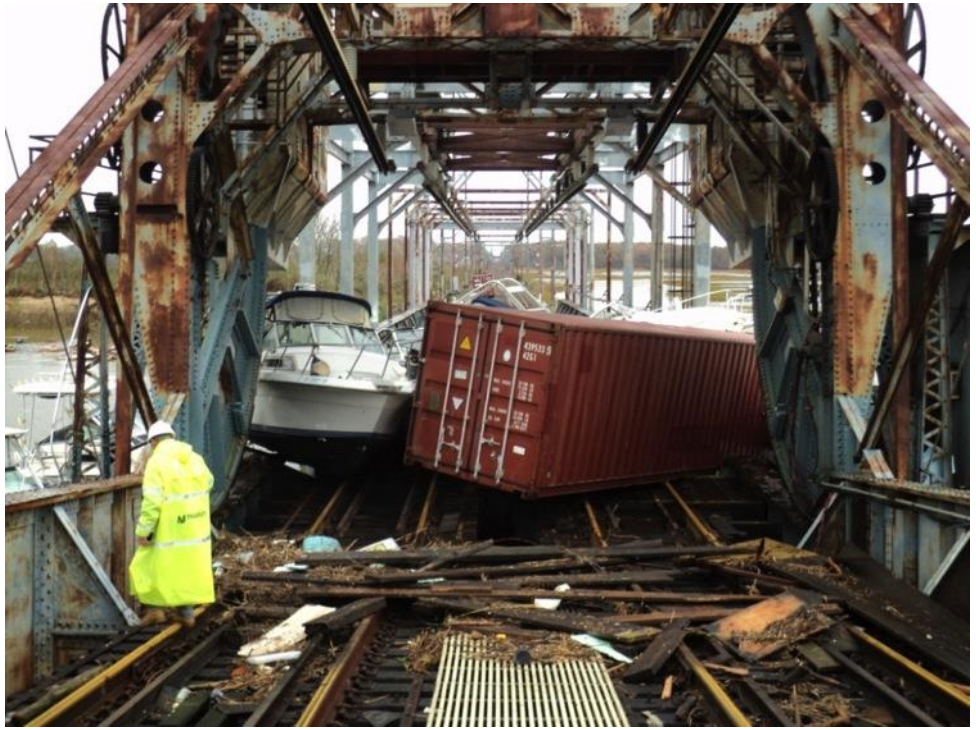
- Superstorm Sandy caused major disruption to critical infrastructure in NY & NJ
- Impact to economy
  - and cost of repairs
  - are in the $Billions
- Re-build efforts emphasize resilience



New Jersey Transit Rail System

City of Hoboken, New Jersey

Flood Maps for Hoboken

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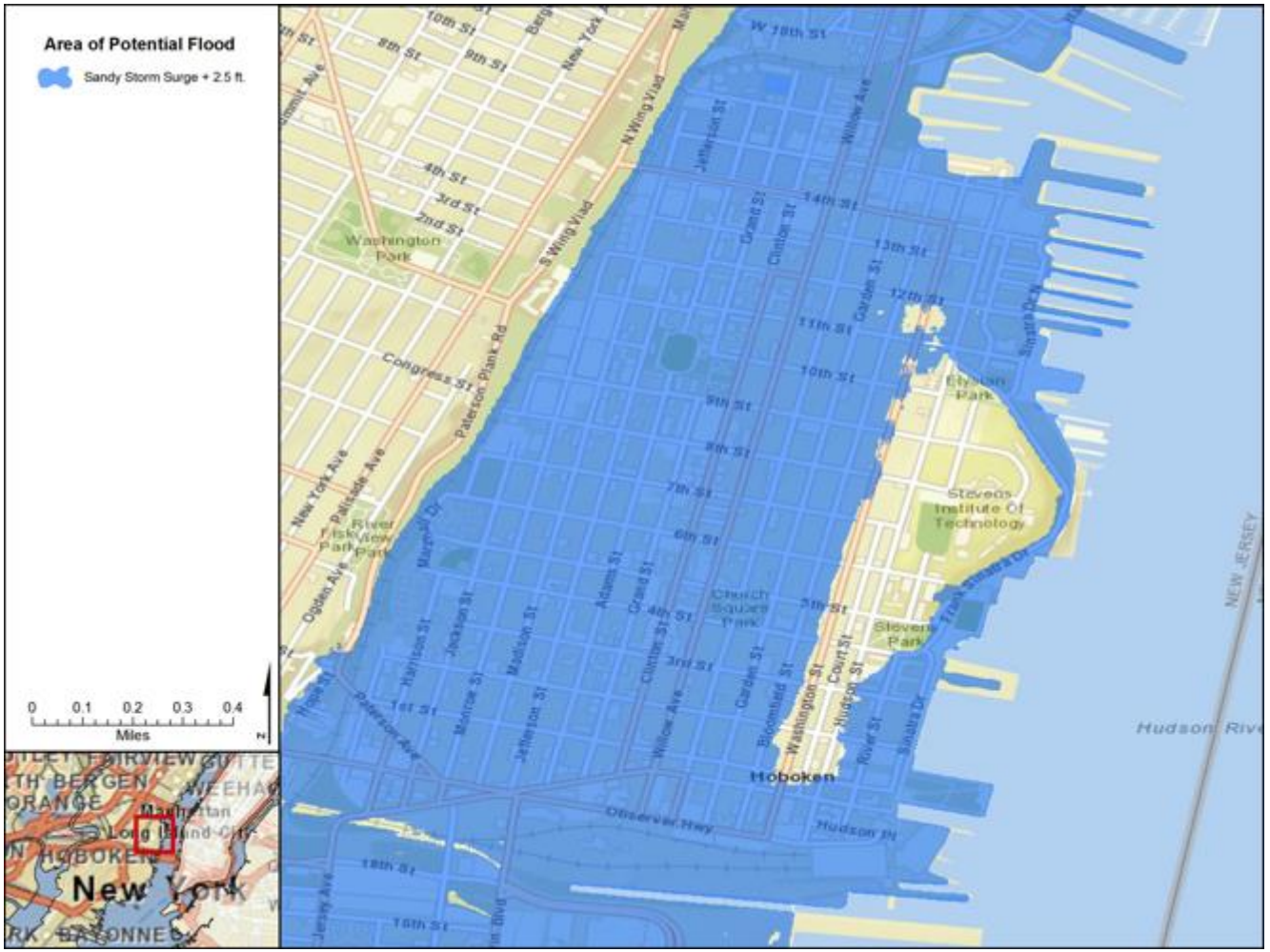
FEMA 100 Year Flood + 2.5 Feet



Hoboken Performance Objectives

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- Supply electric power to facilities during a blackout and/or a flooding condition at 19.5 feet above MSL.
- Microgrid must be able to supply power continuously for 7 days.
- Microgrid will be isolated from the utility when operating
- PV and CHP will operate continuously
- Ability to withstand loss of largest generator without loss of load in individual building or microgrids forming clusters of buildings

Performance Metrics Used

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- Design Basis:
  - Operate during flooded conditions
  - Operate blackout condition
- Frequency of load interruption during flooded or blackout conditions
- Total load not served per hour during flooded or blackout conditions

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Least cost topology for a single large microgrid (not used)

COOPR

Mixed Integer Optimization

Early Solution Subset: Steiner Tree Problem

Objective: minimize cost
Constraints:

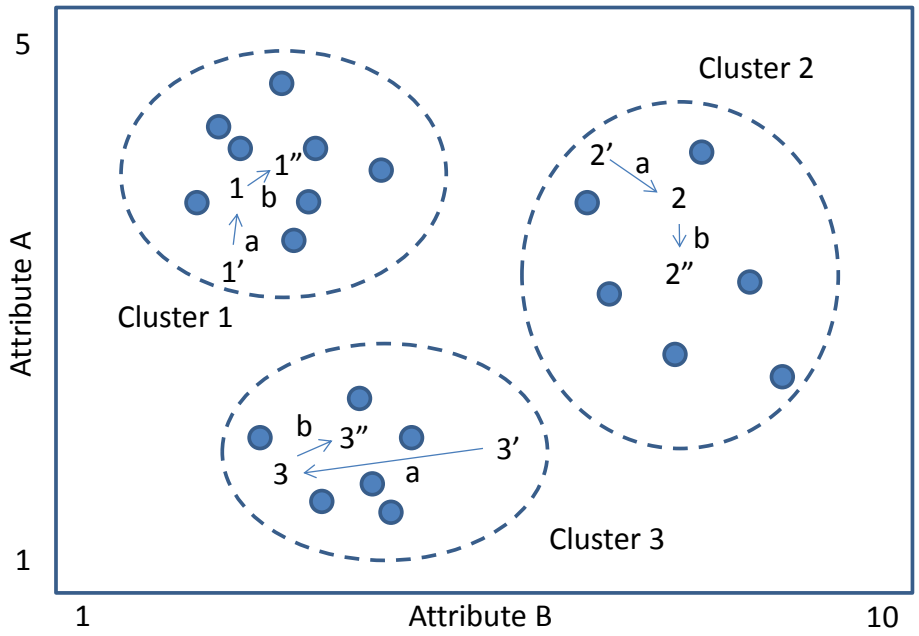
- **Serve all loads**
- **$300/linear foot**
- **$20K for a junction**

Solution: $6.7M for Trenching – with an optimality gap of 5%.

NEXT:

- **Validate Performance**
- **Check Other Topologies**
- **Place Generation**

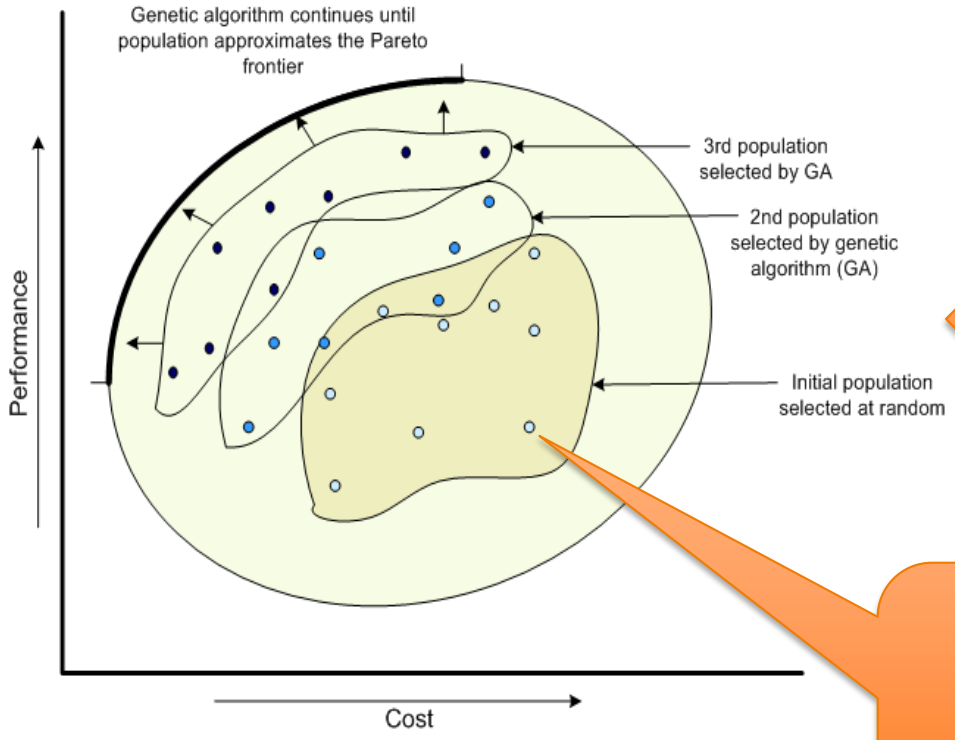
Cluster Analysis to Group Buildings into Microgrids



Example K-means clustering with 3 Clusters

- **Find the best location and subset of microgrids**
  - **K-means clustering is used**
  - **Results in lower costs**

Pareto Optimality Using Genetic Algorithms

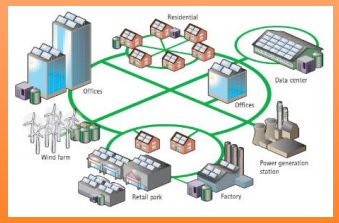


Topology

Performance

Event Driven Simulation

Monte Carlo Analysis



Each dot is a different microgrid layout

Hoboken Microgrid Solution

Dual Microgrid Topology, 54 Buildings

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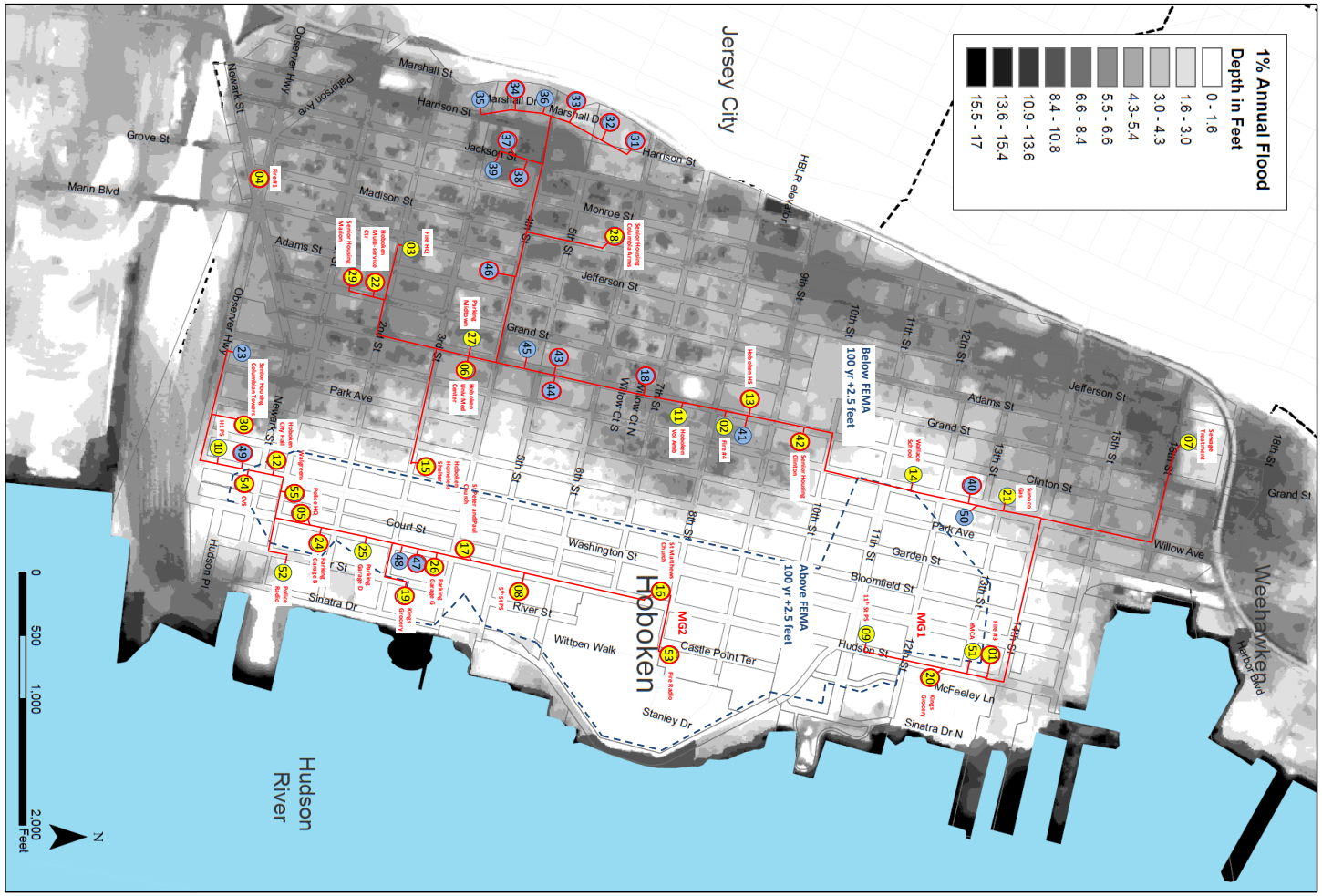
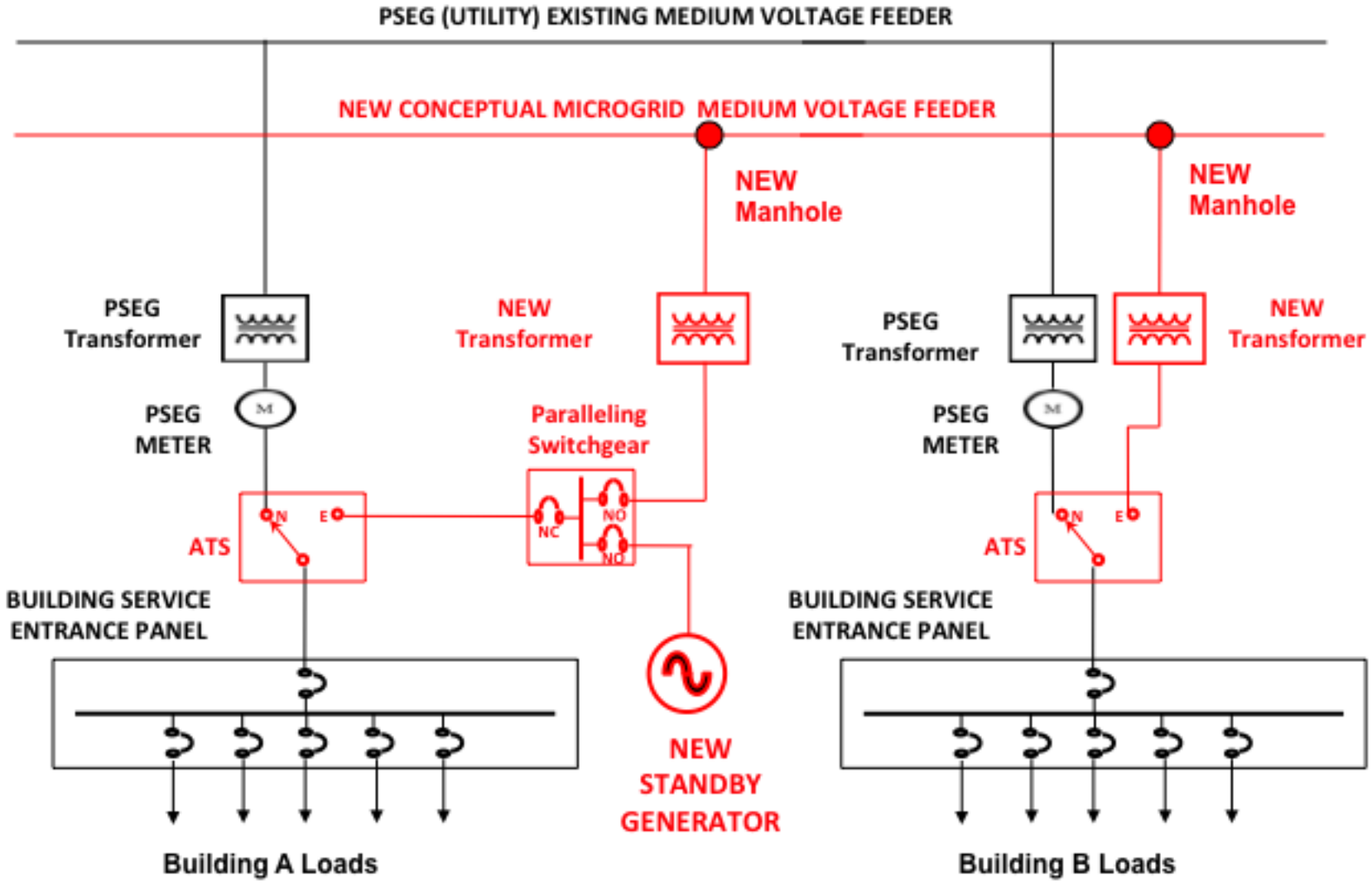


UBS solution A clusters

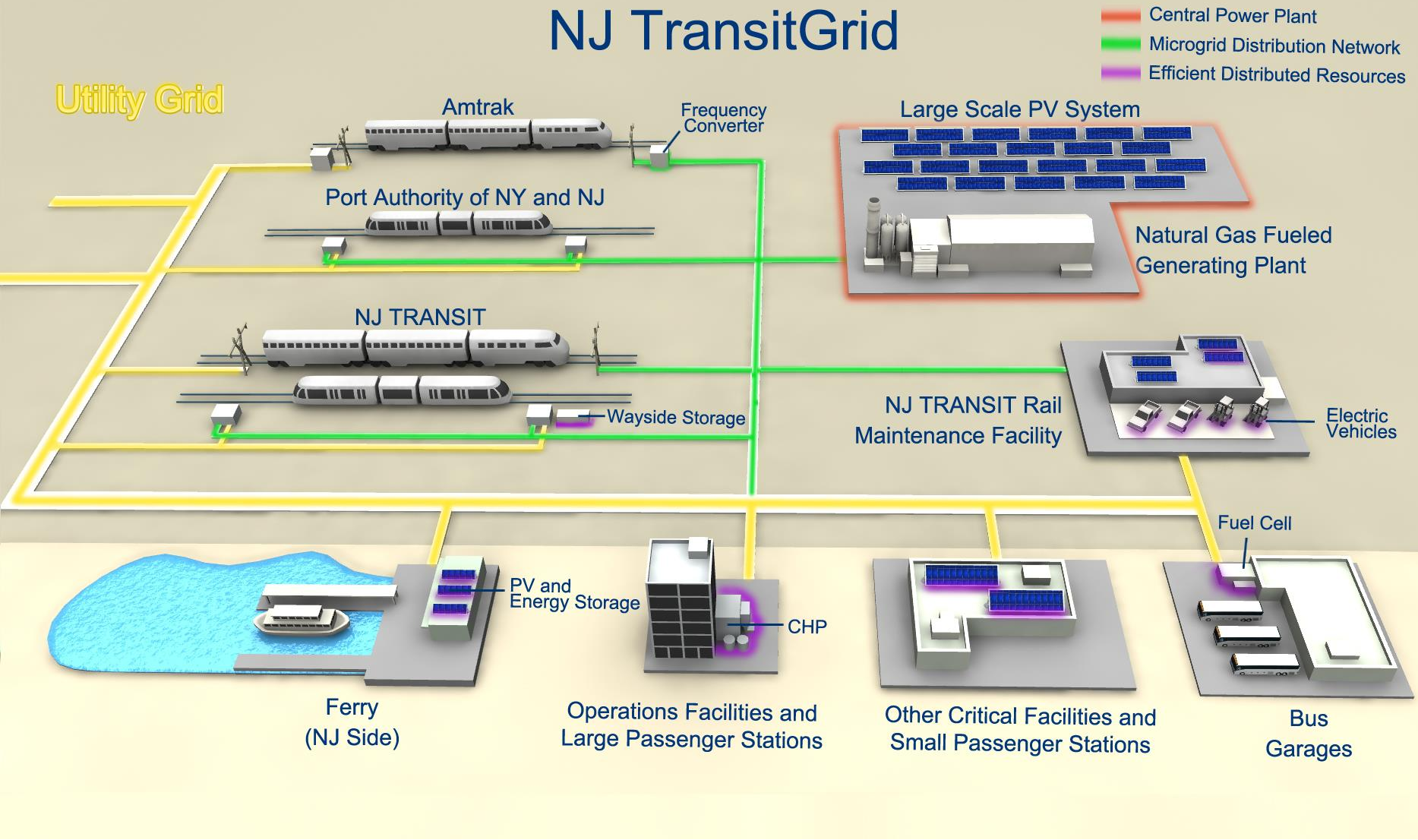
Facility Connections



Building A Loads

Building B Loads

NJ TransitGrid



Basic NJTransitGrid Concept

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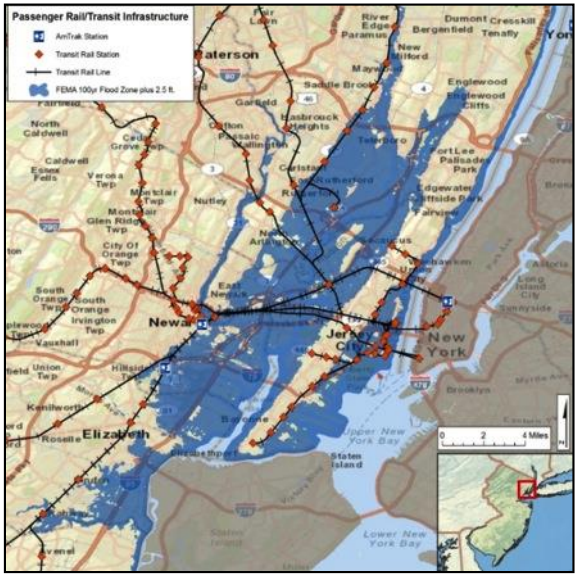
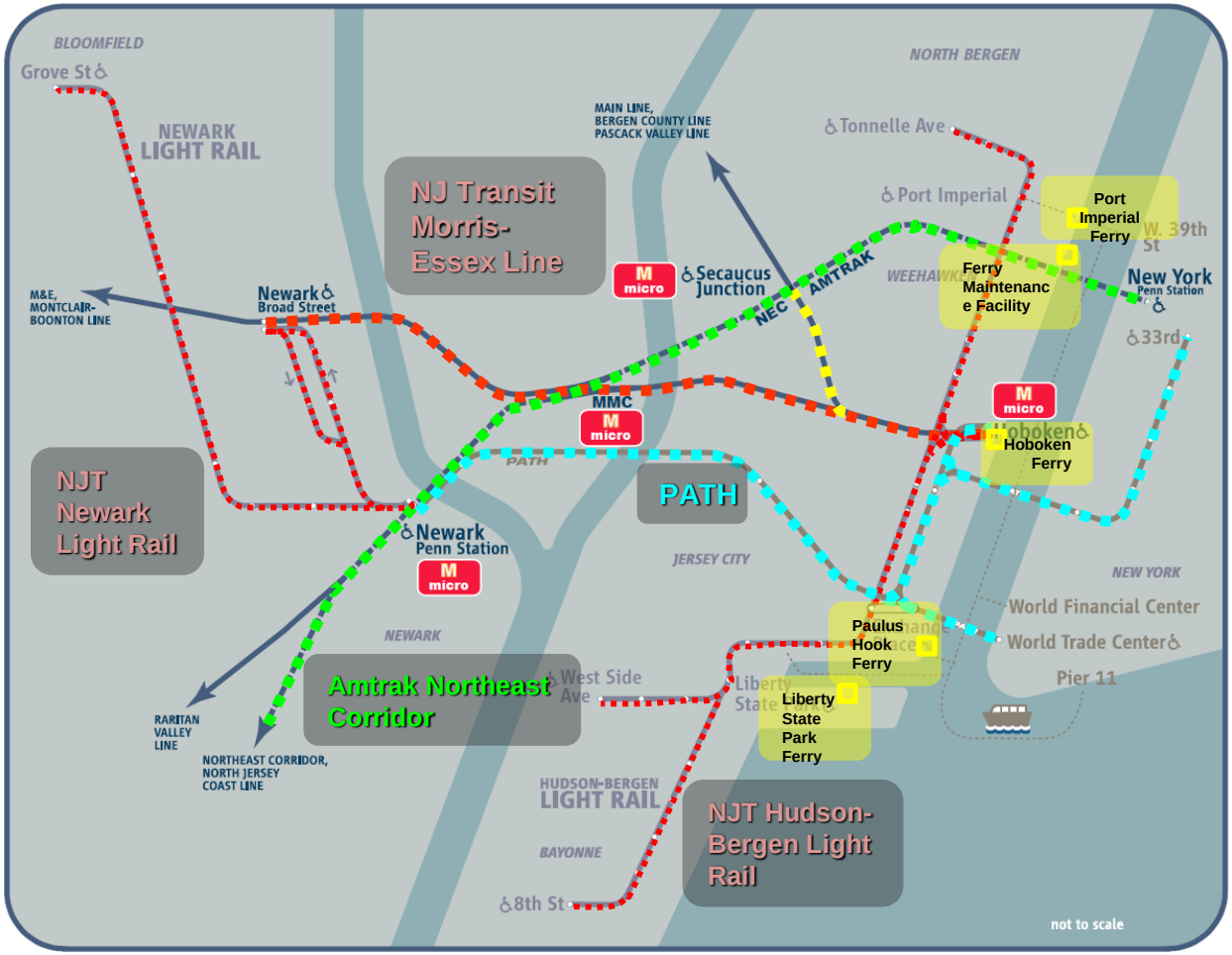
1. Traction Power Microgrid
   - Large conventional generation plant and feeder network
   - Connection to existing traction infrastructure
   - Connection to adjacent rail loads: signal, pumps, fans, switch motors/heaters, some passenger terminals
2. Separate DG systems for facilities
   - Operations buildings and other facilities not connected to the traction microgrid due to cost or other reasons
3. Generator sells power to the market when no contingency exists.

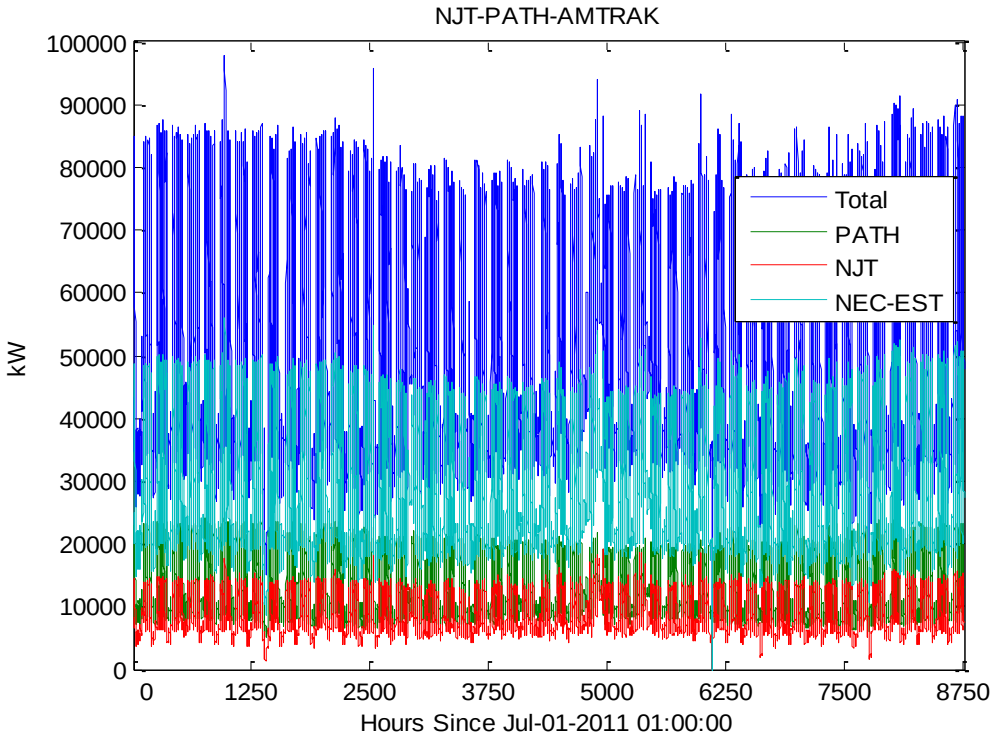
Designs include PV, CHP, storage, and demand response

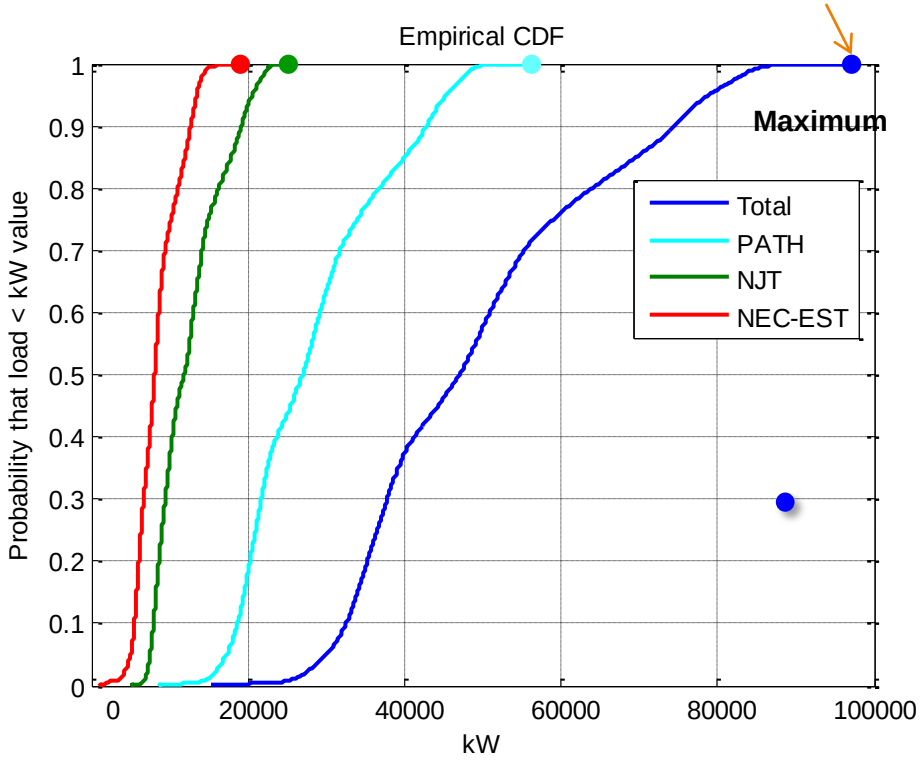
New Jersey Transit Microgrid



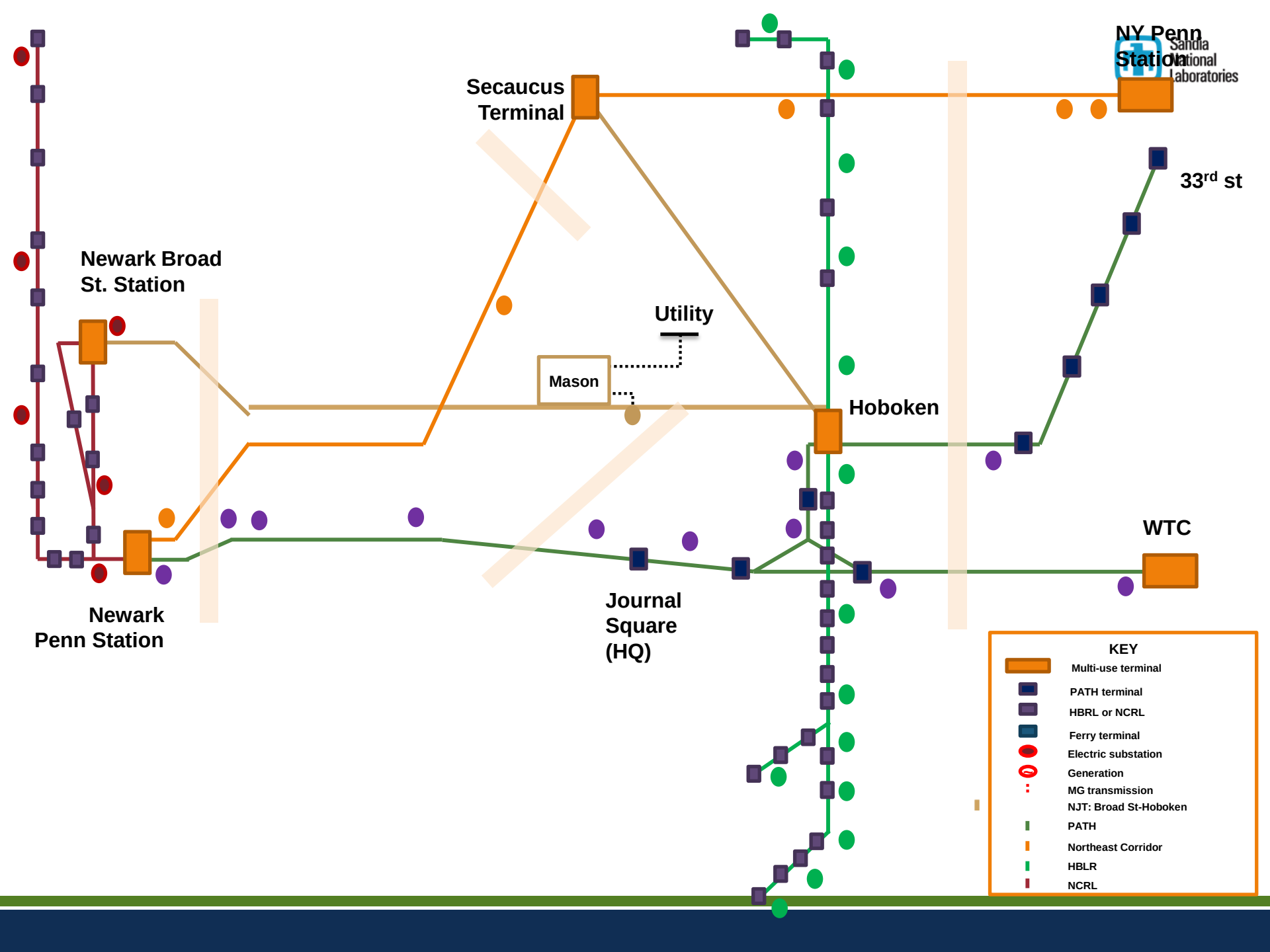


Electrical Demand Analysis





Note that total hourly demand is below 80MW 95% of the time.


NY Penn Station
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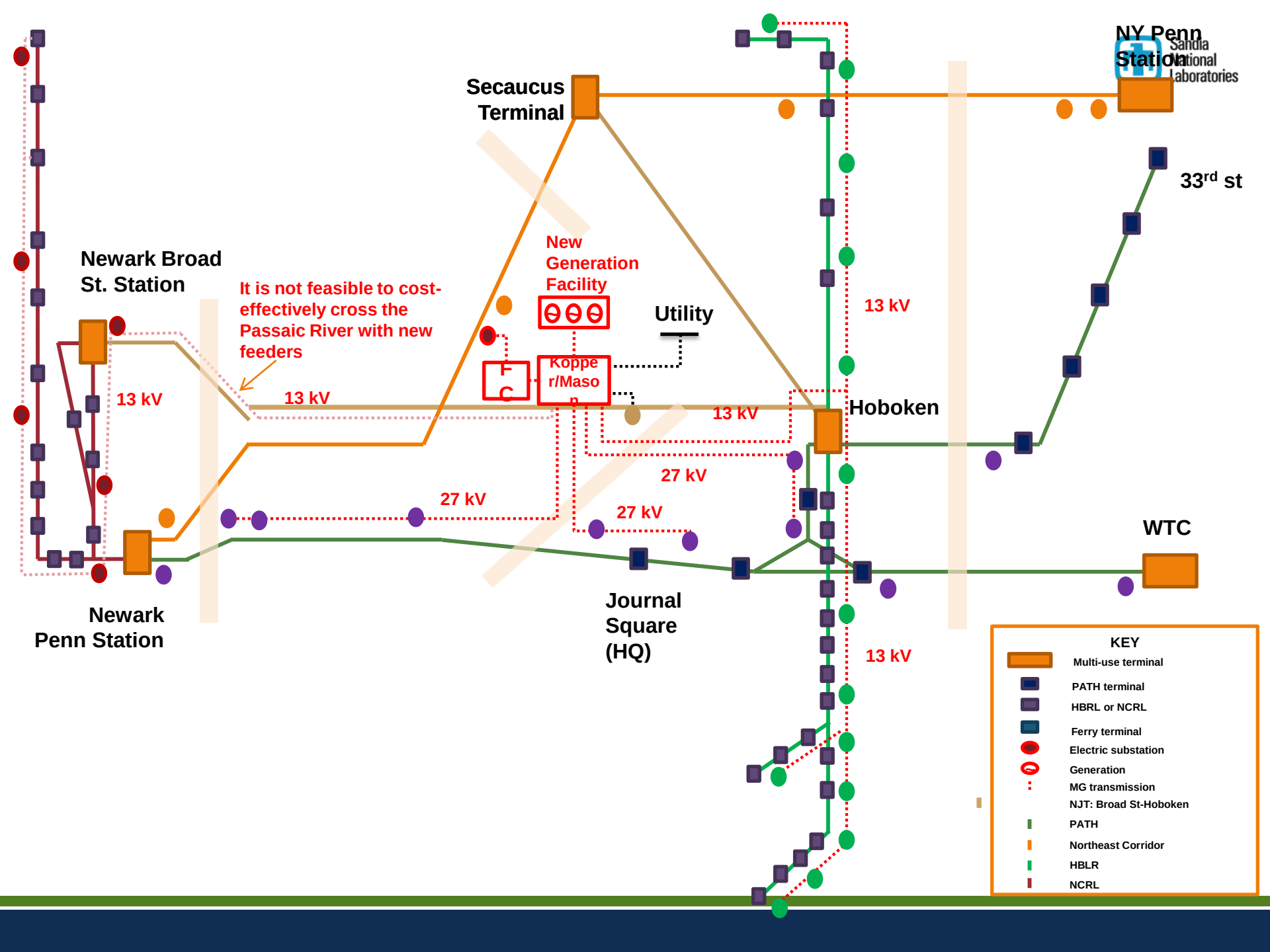
Secaucus Terminal
33rd st
Newark Broad St. Station
Utility
Mason
Hoboken
WTC
Newark Penn Station
Journal Square (HQ)
KEY
Multi-use terminal
PATH terminal
HBRL or NCRL
Ferry terminal
Electric substation
Generation
MG transmission
NJT: Broad St-Hoboken
PATH
Northeast Corridor
HBLR
NCRL


NY Penn Station
Secaucus Terminal
33rd st
Newark Broad St. Station
It is not feasible to cost-effectively cross the Passaic River with new feeders
New Generation Facility
Utility
F C
Koppe r/Maso n
13 kV
13 kV
13 kV
13 kV
13 kV
27 kV
27 kV
27 kV
Hoboken
WTC
Journal Square (HQ)
Newark Penn Station
Sandia National Laboratories
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END