Integrated Central Energy Systems
At Princeton University

District Energy, CHP, Microgrids: Resilient, Efficient Energy Infrastructure
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Room G50 Dirksen Senate Office Building

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Simple Take-Aways

Macro-grid with microgrids can deliver higher reliability with lower total installed capacity.

Highly-integrated microgrid systems exist today.

They offer numerous benefits to the host, local community, and larger grid including: financial, reliability, resilience, environmental, diversified risk, and grid services.

Princeton offers one example of thought-process and technologies.
Simple Microgrid Concept

Central Utility Power Station

KWH Utility Meter

Synchronizing Isolation Breaker

Local Generator

Local Power Demands

KWH Utility Meter

Isolation Breaker

Local Power Demands
Energy Demands at Princeton

- > 180 Buildings
  - Academic
  - Research
  - Administrative
  - Residential
  - Athletic
## Energy Equipment & Peak Demands

### Electricity
- (1) Gas Turbine Generator  
  - Rating: 15.0 MW  
  - Peak Demand: 27 MW
- Solar Photovoltaic System  
  - Rating: 4.5 MW

### Steam Generation
- (1) Heat Recovery Boiler  
  - Rate: 180,000 #/hr
- (2) Auxiliary Boilers @ 150 ea.  
  - Rate: 300,000 #/hr  
  - Peak Demand: 240,000 #/hr

### Chilled Water Production
- (3) Steam-Driven Chillers  
  - Tons: 10,100 Tons
- (5) Electric Chillers  
  - Tons: 10,700 Tons  
  - Peak Demand: 15,000 Tons
- (1) Thermal Storage Tank  
  - Ton-hours: 40,000 Ton-hours
  - *peak discharge: 10,000 tons (peak)
Plant Energy Balance

- PSEG Electricity
- Natural Gas
- #2 Diesel Fuel Oil
- Biodiesel Fuel Oil
- Gas Turbine
- Heat Recovery Steam Generator Duct Burner
- Auxiliary Boilers
- Backpressure Turbines
- Chilled Water & Thermal Storage Systems
- Solar PV Electricity

Flow routes:
- Electricity to Gas Turbine
- Steam to Heat Recovery Steam Generator Duct Burner
- Chilled Water to Auxiliary Boilers
- Chilled Water to Chilled Water & Thermal Storage Systems
- Electricity to Backpressure Turbines
- Steam to Backpressure Turbines
- Chilled Water to Chilled Water & Thermal Storage Systems

Campus Energy Users
- Electricity
- Steam
- Chilled Water
Campus District Energy Systems
Combined Heat & Power, “Cogeneration”

- Fuel & Water
- Air
- Gas Turbine
- Power Turbine
- Gearbox
- Electric Generator
- CO Catalyst
- Feed Water
- Heat Recovery Boiler
- Hot exhaust Gas
- Exhaust Gas
- Steam
- AC Electricity
How Much More Efficient is Combined Heat & Power?

Gas Turbine Simple-Cycle Efficiency
Oct 1, 2013 - Feb 14, 2014

Cogeneration System Total Efficiency
Oct 1, 2013 - Feb 14, 2014
Chiller

Cooling Tower

Hot

Cool

Warm vapor

Warm water from HTX or tank ~ 56° F

Thermal Storage Tank

Cold water To HTX or tank ~ 32° F

Plate & Frame Heat Exchanger

Warm water from Campus ~ 58° F

Cold water To Campus ~ 34° F

Chilled Water Thermal Storage
Thermal Energy Storage Tank
Temperature Stratification
Main Campus Power, Generated & Purchased
During PV System Testing    August 30, 2012

Charlton St Import MW
Elm Drive Import MW
CoGen Output MW
West Windsor PV Output MW
Purchased Power and Power Price
During Solar PV Testing  August 30, 2012

[Graph showing Purchased Power and Power Price]

- **Total Campus Import, MW**
- **PSEG LMP + Delivery, $/MWH**

[Legend for graph]

[Grid for graph]
When it goes right...

Hi Ted,

This is Peter Maag of the cross country team. I was in contact last year to organize a power plant tour for the team over one of our breaks. I graduated this spring, but I happened to be on campus this past week throughout the storm. Just wanted to make sure you got at least one well-deserved fan letter for keeping the lights on.

When I saw the news that a 100 year storm was about to slam Princeton while I visited, I was immediately grateful that I would be on campus. I was pretty confident that it would be one of the most reliable places for power in the whole region. I had to work remotely for a couple days, so power was essential. Thanks for keeping the juice flowing throughout my stay!

By this point, you've probably realized that I have not mentioned the Princeton cogeneration plant. I'm assuming this is common. That being said, I'd love to hear a war story on storm. Did anything out of the ordinary happen (or not happen) that you'd like to share?

Peter Maag
Hurricane Sandy Student Video

Utility Grid With Simple Redundancy

12 x 50 MW = 600 MW Demand
600 MW + 600 MW Back-Up = 1200 MW Installed Generation
“N-1 Redundancy”
Utility Grid Vulnerability Points

12 x 50 MW = 600 MW Demand, 600 MW + MW Back-Up

600 MW Central Utility Power Station

600 MW Central Utility BACK UP POWER Station
Utility + Distributed Microgrids = Diversity

12 x 50 MW = 600 MW Demand

400 MW Utility + 400 MW Microgrids = 800 MW Installed Capacity

“Near N-2 Redundancy” + Reduced Scale of Emergencies