Energy Conservation & Carbon Reduction
At Princeton University

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Bill Broadhurst, PE, CEM, LEED<sup>AP</sup>
Campus Energy Manager
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
    - Capacity: 180,000 #/hr
  - (2) Auxiliary Boilers @ 150 ea.
    - Capacity: 300,000 #/hr
    - Peak: 240,000 #/hr

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

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

Campus Energy Users
Princeton Economic Dispatch System

- PJM Electric Price
- NYMEX gas, diesel, biodiesel prices
- Biodiesel REC value & CO₂ value
- Current Campus Loads
- Weather Prediction
- Production Equipment Efficiency & Availability
- “Business Rules”
- Historical Data

ICETEC

- Generate/Buy/Mix
- Preferred Chiller & Boiler Selections
- Preferred Fuel Selections
- GT Inlet Cooling Mode
- ICAP & Transmission Warnings

Operating Display

Historical Trends

Live feedback to Ice tec

Operator Action
Energy Management Controls

630AM-6PM Mon-Fri
On Call Policy Nights / Weekends
Energy Management Controls
Point Count

Point count growth has accelerated in recent years due to the following:

1. Construction of new critical buildings with complicated automation and monitoring requirements (i.e. Neuro, HPCR, Andlinger, etc.)
2. Energy conservation projects (i.e. Carl Icahn, East Pyne/CG, Fine, etc.)
3. Integration to more 3rd party devices over IP networks for use by facilities personnel, building administrators, researchers, grad students and others (i.e. Freezers, UPS, ORAC's, Humidifiers, VFD's, rainwater systems, lighting panels, animal watering systems, etc.)

Integration to 3rd party devices over IP Networks requires virtual points. Virtual points are more time consuming / difficult to manage than physical points. Instead of 4-20mA or 0-5V signaling, it entails Modbus or BACnet integration, protocol gateways and requires much more network troubleshooting.

A few examples of this virtual point growth since ~2012 are the following from ALC:

- **Athletic Lighting** 992 points 3%
- **Energy Metering (steam, electric, chilled water)** 11,344 points 40%
- **HPCR BCM (electric sub metering)** 12,241 points 43%
- **HPCR Central Plant & Alarming** 3,957 points 14%
- **Total** 28,534 points 100%

In addition, Control System Optimization Platforms (i.e. PACBAM) are installed to analyze most points in our databases to support energy conservation and greenhouse gas goals.

Second Control Room Operator Hired in 2001. 41,200 points in the databases

Third Control Room Operator Hired in 2012. 90,474 points in the database

2016
Current point count
188,842
Campus CO$_2$ Emissions by Source
Future Emission Reductions

Campus CO2 Emissions including Future Emission Reduction Projects

- Projected 2020 Emissions w/ New Construction loads and no ECMS: 114,255 MT CO2
- 2015 Emissions: 112,823 MT CO2

- Distribution System Improvements 6%
- Lighting Improvement Projects 22%
- Building HVAC Replacements 5%
- Control System Optimization 11%
- HVAC Improvement Projects 14%
- Central Plant Efficiency 22%
- Photovoltaics 16%
- Undetermined 4%

Base Year: 1990
Start Year: 2007
Energy Saving Projects

- Cogeneration Plant
- Thermal Storage
- Centralized EMS
- Backpressure steam turbines
- Building heat recovery
- Solar
- Pump / Motor / VFD / Controls
- Free cooling heat exchanger
- LED Lighting Retrofits
- Steam Traps
- Building Heat Recovery
- Control system optimization
- Lab air change reduction
- Occupancy Sensors
Thank you!
EXTRA MATERIAL
Ongoing Opportunities

- Retro-commissioning, continuous commissioning
- Ground Source Heat Pumps
- Variable Frequency Drives
- Chilled Water Controls Optimization
- Real-time emissions calculation
- Energy Star & Smart Start grants as applicable
- Use Condensate to pre-heat Domestic Hot Water
- Biodiesel
- District Hot Water
- CHW-HTW Heat Pumps
- Ultra-efficient buildings
# Steam v. Hot Water District Energy

## District Steam
- Smaller pipes (higher delta-T)
- Tunnels & vaults w/ supports & custom insulation
- Expansion/contraction
- Steam Traps, water loss
- Higher thermal losses
- Complex flow metering
- Easier/cheaper to design building mechanical equipment
- Can be noisier
- Very long history. Well-developed designs. Mature support industry.
- Poor maintenance can result in catastrophic failures
- Very hard to store

## District Hot Water
- Larger pipes (smaller delta-T)
- Direct-buried, pre-insulated
- Minimal expansion/contraction
- Near zero water loss
- Lower thermal loss
- Straightforward flow metering
- Requires more careful design and possibly more investment in the building.
- Can be quieter
- Less common especially in US
- Not as much support industry
- Enables district ground-coupled heat pumps & solar hot water
- Easier to store
Backpressure Turbine - Generators
HRSG & Auxiliary Boilers
HRSG & Auxiliary Boilers

Fig 8: Watertube boilers. A-type boiler, top; D-type boiler, center; O-type boiler, bottom.
Campus Microgrid and Other Models
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
Microgrids Add Reliability

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Local Generator

Local Generator

Local Generator
Microgrid Options

Central Utility Power Station

KWH
Utility Meter

Synchronizing Isolation Breaker

GT, Diesel, Micro-turbine
Battery or flywheel

Economic Dispatch

reciprocating gas engine, solar PV, wind, micro-hydro...

buildings
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 \times 50 \text{ MW} = 600 \text{ MW Demand}, \ 600 \text{ MW} + \text{ MW Back-Up}
Utility + Distributed Microgrids = Diversity
Increased Resiliency, Less Idle Capacity

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

200 MW Central Utility Power Station

50 MW Microgrid (Only Critical Loads In Island)

150 MW Microgrid (100% in island)

100 MW Microgrid (100% in island)

Synchronizing Isolation Breaker

100 MW Microgrid (Only Critical Loads In Island)

200 MW Central Utility BACK UP POWER Station
Princeton Solar Photovoltaic System

**Project Scope**
- 5.2 Megawatts
- 8.2 Million kWh (enough to power 700 Homes)
- 27 Acres
- 16,500 Panels
- Operating Lease structure

**Project Benefits**
- 3091 Metric Tons Annual CO2 reduction (6% of Goal)
- Stable, long term, low cost power
- Large Scale, on Campus project
Reduced Annual Steam To Campus