Energy Conservation & Carbon Reduction At Princeton University

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Energy Demands at Princeton



Energy Equipment & Peak Demands

•	Electricity	<u>Rating</u>	Peak Demand
	 — (1) Gas Turbine Generator 	15.0 MW	27 MW
	 Solar Photovoltaic System 	4.5 MW	
•	Steam Generation		
	 — (1) Heat Recovery Boiler 	180,000 #/hr	
	 – (2) Auxiliary Boilers @ 150 ea. 	300,000 #/hr	240,000 #/hr
•	Chilled Water Production		
	 – (3) Steam-Driven Chillers 	10,100 Tons	
	 – (5) Electric Chillers 	10,700 Tons	15,000 Tons
	 – (1) Thermal Storage Tank *peak discharge 	40,000 Ton-hou 10,000 tons (pe	

Plant Energy Balance



Princeton Economic Dispatch System



Energy Management Controls



Energy Management Controls Point Count

200000 T	Point count growth has accelerated in recent years due to the following:
190000 -	-Construction of new critical buildings with complicated automation and
180000 -	monitoring requirements (i.e. Neuro, HPCRC, Andlinger, etc.) 2016 -Energy conservation projects (i.e., Carl Icahn, East Pyne/CG, Fine, etc.)
170000 -	-Energy Meters (electric, steam and chilled water) -Major maintenance projects where standalone (i.e. pneumatic) controls are upgraded. 188,842
160000 -	-Integration to more 3rd party devices over IP networks for use by
150000 -	facilities personnel, building administrators, researchers, grad students and others (i.e. Freezers, UPS', CRAC's, Humidifiers, VFD's, rainwater
140000 -	systems, lighting panels, animal watering systems, etc.)
130000 -	Integration to 3rd party devices over IP Networks requires virtual points. Virtual points are more time consuming / difficult to manage than
120000 -	physical points. Instead of 4-20mA or 0-10 V signaling, it entails Modbus or Bacnet integration, protocol gateways and requires much more
110000 -	network troubleshooting.
100000 -	A few examples of this virtual point growth since ~2012 are the following from ALC:
90000 -	Athletic Lighting 992 points 3%
80000 -	Energy Metering (steam, electric, chilled water) 11,344 points 40% HPCRC BCM (electric sub metering) 12,241 points 43%
70000 -	HPCRC Central Plant & Alarming 3,957 points 14% Total 28,534 points 100%
60000 -	In addition, Control System Optimization Platforms (i.e. PACRAT) are
50000 -	installed to analyze most points in our databases to support energy conservation and greenhouse gas goals.
40000 -	
30000 -	Second Control Room Operator Hired in
20000 -	Operator Hired in 2001. 2012. 90,474 points
	databases databases in the database
10000 -	
0 +	1987 1998 1999 1994 1994 1995 1998 1998 1998 1998 1998 1998 1998
	3 3

Campus CO₂ Emissions by Source



Future Emission Reductions



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



Campus Microgrid and Other Models

Simple Microgrid Concept



Microgrids Add Reliability



Microgrid Options



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





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





Princeton University Electrical Use Growth Campus + Energy Plant

Fiscal Year

Reduced Chilled Water Use



Reduced Annual Steam To Campus



Fiscal Year