Cost Savings and DeCarbonization with CHP

Penn State University
University Park, PA

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KFI Engineers

Paul Moser, PE
Penn State
Land Grant University – est. 1855

19 Campuses
99,133 Students
6,470 Faculty
20,060 Staff
1000 + buildings
30 million sq ft of space
University Park

Campus
• Established by Land Grant
• +40,000 Students on Main Campus
• 7,342 acres of land at UP
• 600 buildings on campus
• 20 million ft$^2$ Building Space
• $4.3$ billion building replacement value
• 34 years average age of buildings

CHP System
• +200 Buildings Served w/steam
• 2 CHP Plants – ECSP, WCSP
• 430/80 kpph Peak/Minimum Steam Demand
• 50/30 mW Summer/Winter Electrical Demand
• 10 mW CHP Electrical Generation
• 17 Miles of Steam Distribution Piping
• 350/50 mgal ECSP/WCSP on site Diesel

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University Park Numbers

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- ~50,000 Students on Main Campus
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- of land at UP
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- CHP Electrical Generation
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- Miles of Steam Distribution
- Piping
- 350/50 mgal
- ECSP/WCSP on site Diesel
Combined Heat and Power – Penn State
Staff of more than 40 Power Plants
18 Operators
8 daylight maintenance
2 supervisors

Distribution
7 Daylight Maintenance
1 supervisor

2 Staff Assistants
CHP – Prior to 2010

West Plant
coal fired

- 30 KPPH
- 100 KPPH
- 100 KPPH
- 100 KPPH
- 100 KPPH

- 240 psig, superheated
- 150 psig
- 13 psig
- 2.5 MW
- 3.5 MW

East Plant
gas fired

- 100 KPPH
- 100 KPPH

- 220 psig saturated
- 150 psig
- 150 psig
$20 million capital investment

$2-2.5 million reduction in utility budget per year
West Plant Conversion to Gas - 2016

West Plant
gas fired

- 150 KPPH
- 150 KPPH
- 38 KPPH

HPS

13 psig

150 psig

240 psig, superheated

2.1 MW

2.8 MW

East Plant
gas fired

- 100 KPPH
- 100 KPPH
- 117 KPPH

HPS

220 psig, saturated

150 psig

150 psig

7.0 kW
**PSU Energy Savings**

- **Annual Savings Since FY 2008-2009**
  - 30 million kwh
  - 35,000 tons coal
  - Total Fossil Fuel use has been flat, but on site electric has increased from 5% to 25%

- **Added over 1.5 million square feet in new buildings in the same time period**

- **Utility Rebates** – received $2M in support of projects

- **Energy Conservation Program Total since 2000:**
  - Annual Avoided Costs for all projects to date: $8.5M
  - Annual Avoided costs based current energy rates: $14M
  - Total invested to achieve current annual avoided cost is $68M
Penn State’s GHG Inventory primarily includes direct emissions and emissions from purchased electricity.

Energy at University Park is the largest contributor.
20% energy reduction in 28m square feet of existing buildings by 2024

DOE – Better Building Challenge

- Provides a Framework for Tracking & Benchmarking
- Highlights Penn State leadership in incorporating energy efficiency into routine business operations
- Opportunity to Showcase Projects (Results & Solutions)
- Consistent with the Energy Program efforts and current funding
- Energy Efficiency Metric to compliment overall GHG Reduction Targets
GHG Emissions Reduction Strategies to 2030
Penn State University

Progress to Date

- Renewable Energy Credits
- Utility Plant Improvements (CT HRSG)
- Green Design
- Energy Conservation / Awareness
- Non-Energy Initiatives
- Greener Grid (AEPS / Hydro Purchase)
- On Site Solar (2MW)
- Utility Plant Improvements (fuel switch)
- Energy Program to 2020
- Energy Program to 2030

Projected Emissions
- 2012 Goal (17.5% below 2005 baseline)
- 35% below 2005 Baseline
- 52% - 2030 goal on track for 2050

Energy Program 2020-2030
$15M @ 15 yr payback to 2030

Additional CT HRSG
Penn State GHG Emissions include stationary sources, purchased electricity, OPP & Fleet vehicles and estimated commuter miles, air travel, waste, refrigerants and animal management.
WC CHP Addition - Goals

Goals

- Increase Firm Steam Capacity
- Increase Efficiency
- Decrease Greenhouse Gas Emissions (16,000 MTCO2e reduction)
- Improve Resiliency
- Electrical System Upgrades
- Budget – 15 Year payback

Initial Plan

- Nominal 7.1MW Gas Turbine
- 250 psig, 126,000 lb/hr HRSG
- Natural Gas Compressor
- New Stack
- Demolition of both Boiler 6, Boiler 8, and DA-6
CHP Sizing Drivers

- Electric Load Matching
- Thermal Load Matching
- Gas Turbine Efficiency
- HRSG Efficiency
- Overall Capacity

<table>
<thead>
<tr>
<th>WC CHP Generation</th>
<th>T70</th>
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<tbody>
<tr>
<td></td>
<td>GT Utilization Factor</td>
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Unfired VS Fired
### CHP Right Sizing (cont.)

#### Electrical Load Profile West Campus Substation

![Graph showing electrical load profile with different load scenarios.](image)

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<tr>
<td></td>
<td>79,800</td>
<td>59,300</td>
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<td><strong>Substation Modifications</strong></td>
<td>82%</td>
<td>94%</td>
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Combined Cycle Option

Benefits

- No Natural Gas Compressor
- Gas Turbine has nearly 99% utilization factor
- Increased Duct Burner Utilization
- Steam Turbine can take swings
- Still meets nominal power production goals
- Maintains Boiler 8 operation
- Space conservation
# T70 vs. T60CC Results

## WC CHP Generation

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<td>100% 52% 79,800</td>
<td>100% 82% 73,500</td>
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<td>94% 82% 63,500</td>
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**Electrical Load Profile West Campus Substation**

- **WC Substation Modifications**
- **T60 Power**
- **T60CC Power**
- **T70 Power**

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**WC CHP Generation**

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<td>82%</td>
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<tr>
<td>Fuel Conversion Eff. Ave. (%)</td>
<td>86.2%</td>
<td>90.4%</td>
</tr>
<tr>
<td>New Total Generation (MWh)</td>
<td>61,300</td>
<td>56,700</td>
</tr>
<tr>
<td>Annual Power (MWh)</td>
<td>74,800</td>
<td>69,800</td>
</tr>
<tr>
<td>Peak Plant Power Production (MW)</td>
<td>12.3</td>
<td>12.2</td>
</tr>
<tr>
<td>CO2e Annual Reduction (tons)</td>
<td>25,600</td>
<td>24,000</td>
</tr>
<tr>
<td>Gas Compressor Required?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Net Annual Savings ($)</td>
<td>$2.72M</td>
<td>$2.71M</td>
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Layout Optimization
Optimized CHP

Result

- Firm Steam Capacity – 92,500 lb/hr HRSG
- Efficiency – Combined Cycle CHP with >$2.7M annual savings
- GHG Emissions – >20,000 MTCO₂ₑ reduction
- Resiliency – 7MW nominal generation, Black Start
- Electrical System Upgrades – New West Campus Switch Station
- 14% peak electrical, 25% of average
- Budget – 12 Year payback
What Else are We Thinking about?
Renewable Fuels
Hot Water Distribution

- Three new District Steam Plants
- New significantly reduced size distribution system
- Increased initial cost
- Reduced maintenance, heat loss & operating costs
Thank you