University of Wisconsin–Madison
Campus Energy 2016

Chilled Water Plant Expansion and Dispatch Techniques at the University of Wisconsin-Madison

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Agenda

- Campus Overview and Utility Summary
- Energy Conservation
- WCCF Chiller Plant Expansion
- Rate Structure and Economic Plant Dispatch
- Active Demand Management
University of Wisconsin Overview

- Founded in 1848
- 13 Schools/Colleges
- Enrollment of 43,389
- 21,796 Employees and Faculty
- 23.3 Million GSF on 936 Acre Main Campus
- 7.0 Million GSF of Research Facilities
- $2.92 Billion Budget
- Ranked 4th Nationally in Research Expenditures
Campus Utility Plants

Walnut Street Heating Plant (WSHP)
- 600,000 PPH Steam (Nat. Gas)
- 11,500 Tons Chilled Water (Electric)
- 9,000 Tons Chilled Water (Steam)

West Campus Cogeneration Facility (WCCF)
- 400,000 PPH Steam
- 30,000 Tons Chilled Water (Electric)
- 100 MW Combustion T/G (Nat. Gas)
- 68 MW Extraction/Condensing Steam T/G

Charter Street Heating Plant (CSHP)
- 1,200,000 PPH Steam (Natural Gas)
- 25,500 Tons Chilled Water (Steam)
- 9.7 MW Back Pressure T/G

Summer 2012 Hydraulic Neutral Balance Point
Campus Utility Summary

• Steam Summary
  • 2.20 Million PPH Total
  • 1.90 Million PPH Firm
  • 1.30 Million PPH Maximum Peak
  • 0.875 Million PPH Current Peak

• Chilled Water Summary
  • 75,700 Tons Total
  • 67,200 Tons Firm
  • 64,000 Tons Maximum Peak
  • 53,000 Tons Current Peak

• Electrical Summary
  • 72.6 MW Maximum Peak
  • 65.7 MW Current Peak
Energy Conservation

- Current Program Began in 2007
- Performance Contracting Partnership with JCI
- Invested Over $60 Million With Simple Paybacks Less Than 10 Years
- Focused Mostly on Energy Conservation in Buildings
- Two Utility Energy Conservation Projects
  - Tunnel Upgrade and Recondition Now (TURN)
  - Central Plant Optimization (On Hold)
Energy Conservation – Net Per GSF

[Graph showing the change in total energy per GSF from FY05 to FY15, with two lines indicating total energy and weather-adjusted total energy.]
Energy Conservation – Total
WCCF Chiller Plant Expansion

- 20,000 Tons Existing Capacity
- Build-Out of WCCF Site for 30,000 Tons Additional Capacity (50,000 Tons Ultimate)

Scope
- Two 5,000 Ton Dual Compressor Chillers
- Headered Pumping With VSD’s
  - Two 25,000 GPM Chilled Water Pumps
  - Two 25,000 GPM Condenser Water Pumps
- Four Cooling Tower Cells (Two Extra)
- Piping, HVAC and Digital Controls
- 54” Diameter Chilled Water Piping
- 84” Diameter Condenser Water Piping
WCCF Chiller Plant Expansion
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WCCF Chiller Plant Expansion

• Construction/Commissioning Challenges
  • Excavation Around Active Chilled Water Piping
    • A 2 Inch Hole Can Reduce The System Pressure from 105 PSIG to 40 PSIG in Less Than 5 Minutes!
  • Essentially Four (4) Chilled Water Plants Serving Campus Distribution System
  • Equipment Dispatch and Distribution Control Accomplished Manually
  • Historically All Plants Controlled by $\Delta P$
  • Implementing Flow Control Strategies
  • Local Control Strategy Designed Around Chiller Plant Optimization
  • Flow/$\Delta P$ Interaction With Three (3) Hydraulically Adjacent Chilled Water Plants
• Schedule
Energy Conservation vs. Plant Expansion

- Was Expansion Necessary?
- Both Efforts Began in Late 2000’s
- 2012 Chilled Water
  - 65,700 Tons Installed
  - 57,200 Tons Firm
  - 64,000 Tons Peak
- 2015 Chilled Water
  - 75,700 Tons Installed
  - 67,200 Tons Firm
  - 53,000 Tons Peak
- Economic Dispatch Now Possible with 46%/54% Steam/Electric Drive
Rate Structure – Energy

• Campus Usage Charges (MG&E SP-3):
  • $0.0386/kWh (Summer On-Peak)
  • $0.0250/kWh (Summer Off-Peak)
  • $0.0371/kWh (Winter On-Peak)
  • $0.0250/kWh (Winter Off-Peak)
  • * Billable kWh = Usage minus CSHP Turbine kWh production

• WCCF Usage Charges (MG&E SP-3):
  • Gas Rate X 8,500 Btu/kWh (Winter On-Peak Only)
    • Firm Natural Gas Service, Daily Price (MGE LS-1)
  • $0.0386/kWh (Summer On-Peak)
  • $0.0250/kWh (Summer and Winter Off-Peak)

• Campus Natural Gas Charges (DOA – Constellation Energy):
  • $3.66/MMBtu (2015 Average)
Rate Structure – Demand

- **WCCF <17MW Demand Charges:**
  - $0.00000/KW/Day (All Periods)

- **Campus & WCCF >17MW Demand Charges (SP-3):**
  - $1.16017/KW/Day ($34.8/kW) – Summer On-Peak
  - $1.00767/KW/Day ($30.2/kW) – Winter On-Peak

- **Campus Demand Credit (SP-3):**
  - $0.46/KW/Day (Nominated Generator Output)
# Chilled Water Plant Dispatching

- **Chilled Water Production Costs ($/Ton-Hour)**

<table>
<thead>
<tr>
<th></th>
<th>On-Peak</th>
<th>Off-Peak</th>
<th>Cost/Month</th>
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</thead>
<tbody>
<tr>
<td>WCCF (New &lt;17 MW)</td>
<td>$0.031</td>
<td>$0.020</td>
<td>$ 87,600</td>
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<tr>
<td>WCCF (Existing &lt;17 MW)</td>
<td>$0.033</td>
<td>$0.021</td>
<td>$ 93,000</td>
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<tr>
<td>CSHP/WSHP Steam</td>
<td>$0.099</td>
<td>$0.042</td>
<td>$226,500</td>
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<tr>
<td>WSHP/WCCF (New &gt;17 MW)</td>
<td>$0.150</td>
<td>$0.020</td>
<td>$231,400</td>
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<tr>
<td>WCCF (Existing &gt;17 MW)</td>
<td>$0.159</td>
<td>$0.021</td>
<td>$245,900</td>
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Notes: Production costs for steam turbine drive chillers estimated using natural gas at $3.66/MMBtu. Cost/Month is based on 5,000 Tons of capacity and design energy/steam input.
Forecast vs. Actual Demand

- Prior to 2015, Electric Meters Were Not Totalized By Campus

- January Through March Higher Than Forecast Due to Campus Demand Charges for Chiller Operation at WSHP vs. WCCF

- “Business As Usual” Chiller Dispatch in June Through August

- Active Demand Reduction In September
  - No On-Peak Campus Electric Chiller Operation
  - Condenser Water Temperature Reset from 70°F to 85°F For All Steam Turbine Drive Chillers
  - Supply Air Temperature Reset from 55°F to 62-65°F in Select Campus Buildings

<table>
<thead>
<tr>
<th>Month</th>
<th>2015 Forecast Demand (kW)</th>
<th>2015 Actual Demand (kW)</th>
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<tbody>
<tr>
<td>Jan</td>
<td>54,387</td>
<td>57,435</td>
</tr>
<tr>
<td>Feb</td>
<td>54,790</td>
<td>58,198</td>
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<tr>
<td>Mar</td>
<td>54,555</td>
<td>57,467</td>
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<tr>
<td>Apr</td>
<td>54,096</td>
<td>54,713</td>
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<tr>
<td>May</td>
<td>58,728</td>
<td>57,689</td>
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<tr>
<td>Jun</td>
<td>61,481</td>
<td>60,080</td>
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<td>Jul</td>
<td>63,647</td>
<td>65,515</td>
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<td>Aug</td>
<td>63,337</td>
<td>64,435</td>
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<tr>
<td>Sep</td>
<td>63,108</td>
<td>64,671</td>
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<tr>
<td>Oct</td>
<td>58,994</td>
<td>56,121</td>
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<tr>
<td>Nov</td>
<td>56,839</td>
<td>55,410</td>
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<tr>
<td>Dec</td>
<td>55,123</td>
<td>54,475</td>
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<tr>
<td>Sum</td>
<td>699,085</td>
<td>706,209</td>
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Demand Reduction (September 3, 2015)
Summary

- Campus GSF Has Increased Nearly 21% Since FY05
- Energy Reduction of 25% Per GSF and 9% Total Since FY05
- 10,000 Ton Plant Addition Becomes Year Around Baseload Variable Primary Chilled Water Flow Plant
- WCCF is Most Cost Effective Chilled Water Plant With No Demand Charge up to 17.0 MW On Peak
- Energy Conservation and Chilled Water Plant Expansion Has Allowed UW-Madison to Economically Dispatch Chilled Water Assets for the First Time in Many Years
  - Manual Presently, Hoping For Automated Optimization in Future
- Credibility With Local Utility in Electric Rate Case Discussions
- Future?
  - Chiller Plant Optimization
  - East Campus Electric Chiller
  - Thermal Storage