PLANT OPERATIONAL CHALLENGES
STARTING UP 1MW STEAM TURBINE GENERATOR

EMORY UNIVERSITY
KEN WYSOCKI & JODY DICARLO
Campus Overview
Emory Overview

- 15,451 students
- 33,026 employees
- Approximately 9 million square feet; 130 buildings
- Central Steam Plant 500,000 pph capacity
- Three Central Chiller Plants 20,300 tons capacity
- Utility budget of approx. $35M
# Campus Overview

<table>
<thead>
<tr>
<th>Equipment Name</th>
<th>Year Installed</th>
<th>Boiler Age</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler No. 6</td>
<td>1975</td>
<td>43</td>
<td>100,000</td>
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<tr>
<td>Boiler No. 7</td>
<td>1980</td>
<td>20</td>
<td>100,000</td>
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<tr>
<td>Boiler No. 8</td>
<td>1980</td>
<td>20</td>
<td>100,000</td>
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<tr>
<td>Boiler No. 9</td>
<td>2001</td>
<td>17</td>
<td>100,000</td>
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<tr>
<td>Boiler No. 10</td>
<td>2016</td>
<td>2</td>
<td>100,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>500,000</strong></td>
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</tbody>
</table>
• **UTILITY MASTER PLANNING**

• **DESIGN**

• **START UP & TUNING**

• **OPERATIONS & MAINTENANCE**
Summary from 2013 Study

- Future Campus Expansion requires Approx. 180,000 pph additional capacity
- Recommend 100,000 pph boiler initially to replace Boiler No. 5
- Second 100,000 pph boiler not required until final future buildings
- CHP is not cost effective with current rate structure
- If Georgia becomes deregulated and electric costs increase, re-evaluate CHP
- Backpressure Steam Turbogenerator is cost effective (7 year simple payback)
- BP STG would use 250 psig steam generated from Boiler No. 10 normally generated for campus
Predicted Steam Load increase to 400+ kpph by 2025 due to future expansions
# Steam Demand for Future Capacity

## Future Steam Load Summary

<table>
<thead>
<tr>
<th>YEAR</th>
<th>BUILDING</th>
<th>GROSS AREA (GSF)</th>
<th>SPACE TYPE</th>
<th>UNITARY LOAD (B/HR/GSF)</th>
<th>CONNECT LOAD (PPH)</th>
<th>PEAK LOAD (PPH)</th>
<th>CENTRAL PLANT BOILER PROD. (PPH)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EXIST</strong></td>
<td>EXISTING</td>
<td>6,864,471</td>
<td>--</td>
<td>69</td>
<td>463,400</td>
<td>184,000</td>
<td>200,000</td>
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<tr>
<td>2013 - 2015</td>
<td>ATWOOD ADDITION 31</td>
<td>65,000</td>
<td>CLASSROOM / OFFICE / LAB</td>
<td>92</td>
<td>6,000</td>
<td>8,500</td>
<td>206,500</td>
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<tr>
<td></td>
<td>MCTYIERE HALL DEMO</td>
<td>(26,545)</td>
<td>RESIDENCE HALL</td>
<td>(119)</td>
<td>3,150</td>
<td>(1,278)</td>
<td>205,100</td>
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<tr>
<td></td>
<td>WOODRUFF LIB ADD 39</td>
<td>120,000</td>
<td>LIBRARY</td>
<td>45</td>
<td>6,400</td>
<td>5,400</td>
<td>211,000</td>
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<td>DUC RENOVATIONS 22</td>
<td>26,000</td>
<td>ASSEMBLY</td>
<td>60</td>
<td>1,500</td>
<td>1,500</td>
<td>212,600</td>
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<td>FRESHMAN HALL No. 5 - 35</td>
<td>120,000</td>
<td>RESIDENCE HALL</td>
<td>100</td>
<td>12,000</td>
<td>12,000</td>
<td>225,700</td>
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<td></td>
<td>CSOT - PHASE II 28</td>
<td>66,000</td>
<td>CLASSROOM / OFFICE</td>
<td>40</td>
<td>2,600</td>
<td>2,600</td>
<td>228,500</td>
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<td>EUH HOSPITAL WING</td>
<td>400,000</td>
<td>HEALTHCARE</td>
<td>79</td>
<td>31,400</td>
<td>31,400</td>
<td>262,600</td>
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<td><strong>SUBTOTAL</strong></td>
<td>766,456</td>
<td>--</td>
<td>81</td>
<td>62,060</td>
<td>57,622</td>
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<tr>
<td>&gt; 2016</td>
<td>ACADEMIC BLDG</td>
<td>160,000</td>
<td>CLASSROOM / OFFICE</td>
<td>40</td>
<td>6,000</td>
<td>6,000</td>
<td>269,200</td>
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<tr>
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<td>LAW SCH. EXPANSION 20</td>
<td>40,000</td>
<td>CLASSROOM / OFFICE</td>
<td>40</td>
<td>1,600</td>
<td>1,600</td>
<td>270,900</td>
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<td>BUSINESS SCH LIBRARY</td>
<td>90,000</td>
<td>LIBRARY</td>
<td>50</td>
<td>4,000</td>
<td>4,000</td>
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<td>THEATRE BLDG. 47</td>
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<td>58</td>
<td>4,700</td>
<td>4,700</td>
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<td>MULTIPURPOSE BLDG 32</td>
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<td>6,400</td>
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<td>RESEARCH BLDG 29</td>
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<td>LAB</td>
<td>100</td>
<td>35,000</td>
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<td></td>
<td>OFFICE BUILDING</td>
<td>150,000</td>
<td>OFFICE</td>
<td>40</td>
<td>5,000</td>
<td>5,000</td>
<td>331,900</td>
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<td>HSRB PHASE II</td>
<td>210,000</td>
<td>LAB</td>
<td>100</td>
<td>21,000</td>
<td>21,000</td>
<td>354,700</td>
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<td>CLINIC REPLACEMENT</td>
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<td>HEALTHCARE</td>
<td>60</td>
<td>28,200</td>
<td>28,200</td>
<td>385,300</td>
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<td>HAYGOOD TRIANGLE BLDG</td>
<td>800,000</td>
<td>HEALTHCARE</td>
<td>60</td>
<td>48,000</td>
<td>48,000</td>
<td>437,500</td>
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<tr>
<td><strong>SUBTOTAL</strong></td>
<td>2,440,000</td>
<td>--</td>
<td>66</td>
<td>160,900</td>
<td>160,900</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td>10,072,826</td>
<td>--</td>
<td>67</td>
<td>576,350</td>
<td>402,522</td>
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</tbody>
</table>

- **Complete**
- **Reduction instead of increase**
- **Active Design**

Actual increase due to expansions equal to 50 kpph.

Other expansions currently in progress add another 56 kpph.
Through energy reduction initiatives and commitment to lower EUI for new construction, Emory has reduced energy consumption an additional 10% since 2013.
Energy reduction efforts have more than offset expansions and new construction.

Campus load has decreased over the last several years.

This trend is expected to continue.
DESIGN
Boiler #10 and Steam Turbine were installed in same physical space as Boiler #5 in Steam Plant. There was no building expansion as part of project.
BOILER #10 TUBE DAMAGE

- Emory physical and performance requirements in design proposal resulted in a deviation from standard OEM design and having finned tubes in boiler
- First annual overhaul revealed fin damage from heat/flame
• Emory main steam header is 115 psi.

• Steam Turbine designed with inlet pressure of 250 psi and outlet pressure of 115 psi.

• Boiler #10 was designed to produce 250 psi steam to feed steam turbine.

• Boiler #10 is the only Emory boiler capable of producing 250 psi steam.
• Summertime demand can go below 50,000pph, turbine minimum load is 40,000pph

• Kw output from turbine can only be maximized a few months per year

• No kw production when Boiler #10 is down for overhaul or unplanned maintenance
START-UP & TUNING
Tuning

• Initial start-up tuning on control loops was not responding appropriately for campus demand

• Experienced many boiler trips and loss of steam to campus during first year in operation

• Combination of turbine response, boiler response and operator intervention (how many steam valves open, how many boilers online)

• Maintenance contractor, Elliott (not part of install), reviewed and adjusted steam inlet valve reaction timing and we have had significant improvement
Operations & Maintenance
EFFICIENCY VS RELIABILITY

- Major change in operating philosophy for operators
  - Maximize turbine kw output vs stability of steam supply
  - Multiple boiler vs one boiler operation

Shoulder months
ONE BOILER OPERATION

- Increased opportunities for boiler trip and loss of steam supply to customers
- Building demand and system tuning becomes more critical
  - Hospitals and bad tuned control loops cause rapid demand changes have bigger impact at steam plant
  - Largest demand swings due to weather / HVAC needs
  - Overnight low temperatures and start of the day heating demand sees biggest load swings
**Manual Operation of Turbine Steam Valves**

- Monitor plant load to determine what was best timing to open or close valves

- Running with valves closed increases kw output but limits throughput (system stability issue)

- Running with all valves open maintains throughput but significantly reduces kw output
Operations & Maintenance

- Keeping 4 other boilers active and in rotation has become a challenge
- Similar issue with 2 separate DA tanks
- Operator and maintenance access challenges due to footprint
- No overhead crane for maintenance
- Reused existing orifice plate flowmeters resulting in less accurate metering
LESSONS LEARNED

• **UTILITY MASTER PLANNING**
  • Incorporate energy reduction impact into future load forecasting

• **DESIGN**
  • Involve all end users in up front design considerations, review how system will be operated and get with other universities/companies on lessons learned ahead of design

• **START up & Tuning**
  • After one year of operation, re-evaluate system dynamics and tuning to optimize

• **OPERATIONS & MAINTENANCE**
  • Have a game plan to maximize efficiency and not sacrifice reliability. Document and Communicate!
THANK YOU!

QUESTIONS?