History of Bucknell Energy Production

Bucknell University was founded in 1846 on 450 acres on the banks of the West Branch of the Susquehanna River. It was originally named the University of Lewisburg but was renamed in 1886 by its benefactor, William Bucknell, a Philadelphian who supported the University after the Civil War.

The first utility plant was constructed in the early 1900’s to supply steam from a coal-fired boiler to Roberts, Trax, and Kress Halls. Bucknell replaced the original steam plant in 1949 with a new, much larger coal-fired plant. This plant contained three coal-fired boilers. Two of the boilers were Keeler traveling grate overfeed stoker boilers that had a heat input capacity of 49.5 MMBtu/hr. The third boiler was a Keeler unit with a Detroit Stoker Vibragrate with a heat input capacity of 46.7 MMBtu/hr.

As the campus grew, the coal fired plant struggled to provide sufficient steam flow during peak usage periods. In addition, it became increasingly difficult to abide with the more stringent environmental regulations. The reliability of the plant also began to deteriorate due to aging equipment and systems.

In 1996 these three concerns prompted Bucknell to approve $12 million to replace the coal plant with a new combined heating and power (CHP) system. The new plant was designed with the intent of satisfying the campus’ steam and electrical load for the next 20 years while improving emissions and energy efficiency in a cost-effective manner.

The CHP facility was completed in 1998 and had an immediate effect. Bucknell saw a reduction in emissions and energy costs. The CHP facility saved Bucknell $1.2 million annually over the past ten years, while reducing greenhouse gas emissions by 50% compared to the coal-fired plant. A more detailed look at the emissions reduction can be seen in the table below.

<table>
<thead>
<tr>
<th>Annual Emissions (ton/yr)</th>
<th>1996</th>
<th>2015</th>
<th>Percent Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>94.7</td>
<td>12.9</td>
<td>86%</td>
</tr>
<tr>
<td>CO</td>
<td>112.3</td>
<td>0.7</td>
<td>99%</td>
</tr>
<tr>
<td>VOC</td>
<td>0.9</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Particulate</td>
<td>100.4</td>
<td>0.6</td>
<td>99%</td>
</tr>
<tr>
<td>SOx</td>
<td>703.7</td>
<td>0.2</td>
<td>99.9%</td>
</tr>
</tbody>
</table>

In 2001 Bucknell constructed a central chilled water plant (CWP) adjacent to the CHP facility. With five large new buildings planned for the early 2000’s, Bucknell decided to invest $5 million into a CWP that would distribute chilled water to buildings all over campus. Upon completion, the CWP reduced Bucknell’s energy and maintenance costs by producing chilled water more efficiently.
For most of its history Bucknell produced its cooling through the use of steam absorption and electrical chillers serving individual buildings. These chillers had relatively small cooling capacities and required a large amount of maintenance. The majority of these smaller, inefficient chillers were retired upon completion of the central CWP and distribution system. All of the remaining remote chillers are connected to the distribution system to share capacity and redundancy for the buildings they serve.

**Fuel Consumption and Energy Production**

Bucknell University is comprised of more than 150 buildings totaling nearly 3 million square feet and housing more than 3,600 students. A campus of this size requires a significant and constant energy supply. The CHP plant provides 90-95% of the electricity used on campus, along with supplying steam to 90% of the campus. The CWP supplies chilled water to 70% of the campus. A breakdown of the electrical power, steam and chilled water produced by both plants, along with the fuel consumed in both plants in FY15 is as follows:
Power Generation:
- 6,376 kW peak campus demand
- 34,500 MWh produced by CHP
- 2,800 MWh exported to the grid

Steam Generation:
- 21,400 lb/hr average production
- 62,000 lb/hr peak demand
- 223,000 Mlb of steam produced by CHP

Chilled Water Generation:
- 1,600 tons peak production
- 3,500,000 Ton-Hr produced by CWP

Fuel Consumption:
- 500,000 MMBtu of Natural Gas combusted
- 3,000 MMBtu of Fuel Oil combusted
- 3,200 MWh of electricity purchased

Cogeneration Plant
Cogeneration or CHP refers to a process which derives two forms of energy from a single fuel source. Bucknell’s plant produces both steam and electricity from natural gas. Bucknell’s plant is a combined cycle design, meaning it produces electricity and steam directly from the combustion of fuel and also produces electricity downstream in the process from a steam turbine driven generator. A schematic of Bucknell’s combined cycle cogeneration design is seen below.
This system design was determined to be the most cost effective method of supplying the steam and electrical demands of the campus. Although the Cogen Plant required a substantial initial investment, the plant provides enough savings to justify the initial investment. The plant now provides nearly 100% reliable steam supply to the campus. The plant also produces over 90% of the electricity used on campus and, during much of the year, produces excess electricity for sale back to the local utility. The savings from steam and electrical production combined with the income from electricity sales saves Bucknell over $1M per year in utility costs.

**Electrical Generation**

The Cogen Plant has two prime movers in producing electricity for Bucknell's campus. A Solar Taurus 60 Combustion Turbine and a Murray KG4 Steam Turbine. The Solar Combustion Turbine runs mainly on natural gas but can be fired on No. 2 Fuel Oil in back-up situations. It produces 4,800 kW at ISO conditions and up to 5,500 kW peak. The Murray Steam Turbine reduces high pressure steam (175-225 psig) to low pressure steam (12-13 psig) to produce 1,200 kW at peak conditions. These two turbines allow Bucknell to reliably produce from 5 MW up to 6.7 MW at peak capacity.

At times when campus demand is higher than the available capacity Bucknell purchases electricity from the grid. On the other hand, the plant often produces more electricity than is needed on campus. Operators monitor the prices of electricity and as long as the market price exceeds the fuel cost to generate the excess, Bucknell sells power back to the utility company.

**Steam Production**

In addition to producing electrical power for the campus, the Cogen Plant also produces steam that is supplied to 90% of the campus. The Cogen Plant employs a Heat Recovery Steam Generator (HRSG) that extracts heat from the combustion turbine exhaust to produce up to 25,000 lb/hr of high pressure, saturated steam. The HRSG also contains a supplemental natural gas fired duct burner which increases to HRSG’s capacity to 70,000 lb/hr.

Along with the HRSG, the Cogen Plant contains two Package Water Tube Boilers. Each of these boilers produce 70,000 lb/hr. The two water tube boilers combined with the HRSG provide 140,000 lb/hr peak capacity with a 50% redundancy. Redundancy allows Bucknell to maintain 100% reliable steam production even during maintenance or other events that might otherwise interrupt the steam supply to campus.
The main fuel source for the Package Boilers and the Combustion Turbine is natural gas but all three can operate on No. 2 Fuel Oil as well. A 50,000 gallon oil storage facility holds enough fuel to operate the plant for approximately three days in the event the natural gas supply is interrupted.

**Chilled Water Plant**

**Cooling Production**

The CWP that was completed in 2001 contains two 800 ton Carrier Centrifugal Chillers. As campus continued to grow, an 850 ton York Centrifugal Chiller was added to the CWP in 2007. Then in 2014, an 888,600 gallon Thermal Energy Storage (TES) tank was constructed, providing up to 6,500 ton-hours of cooling capacity. The TES allows Bucknell to store chilled water during off-peak periods when excess generating capacity is available. The TES then discharges chilled water when cooling demand peaks to reduce electricity demand. The system also reduces overall energy consumption by allowing the chillers to operate at higher loads overnight, thereby optimizing the efficiency of the equipment.

With the TES’s operating capacity of 750 tons, the CWP has a total cooling capacity of 3,200 tons. Sometimes this is not enough cooling capacity for the entirety of the campus, so Bucknell still utilizes some chillers outside of the CWP, that are placed in buildings throughout campus. These chillers can be seen in the table below.

<table>
<thead>
<tr>
<th>Location</th>
<th>Chiller Type</th>
<th>Quantity</th>
<th>Operating Capacity (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bertrand Library</td>
<td>Steam Absorption</td>
<td>1</td>
<td>130</td>
</tr>
<tr>
<td>Geiger</td>
<td>Steam Absorption</td>
<td>1</td>
<td>270</td>
</tr>
<tr>
<td>McDonnell</td>
<td>Electric Screw</td>
<td>2</td>
<td>150</td>
</tr>
<tr>
<td>Rooke Science</td>
<td>Steam Absorption</td>
<td>2</td>
<td>300</td>
</tr>
</tbody>
</table>

The absorption chillers play a critical role in supporting the efficient operation of the CHP plant by providing a productive use for the waste heat from the combustion turbine. The chillers provide cooling to their respective buildings but can also supply cooling to the central distribution system when building loads are low.