System Performance Best Practices

Wake Forest University – Winston-Salem, NC (System 21)

Climate Zone	3A
Cooling Degree Days	1512
Heating Degree Days	3162
ISO	Southeast
Local Utility	Duke Energy
2018 State Energy Intensity	5.3

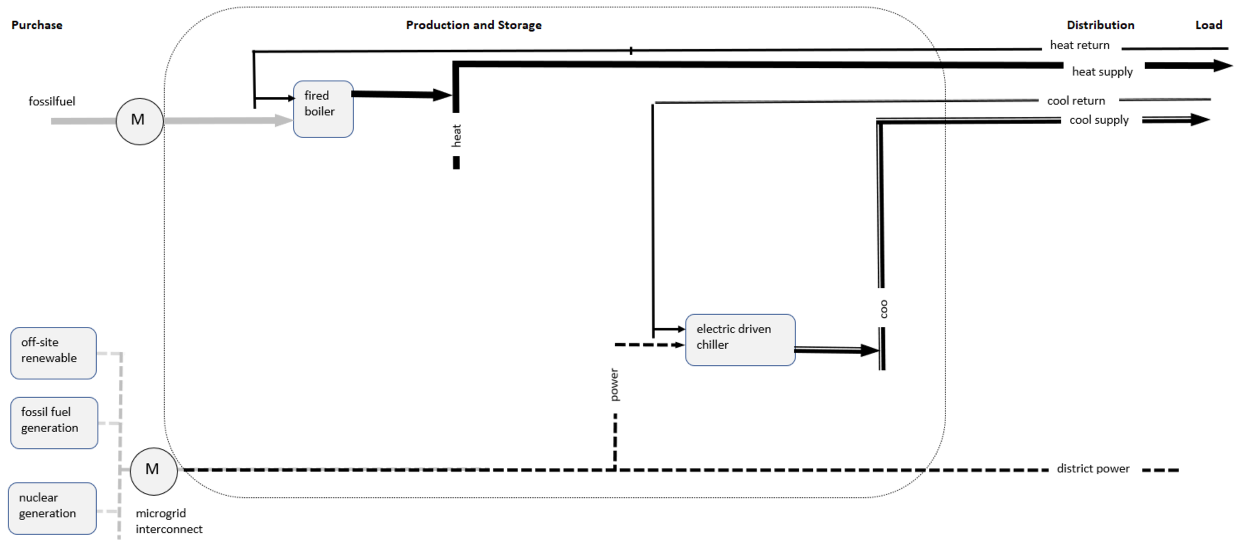
System Profile

Wake Forest University is a mid-sized private research university in Winston-Salem, NC. The 340-acre campus houses over 4,000 students and 3,000 faculty and staff annually. 80 buildings on the main campus (3.5 million square feet) are served by a central cooling and heating district energy system, which produce 6,000 tons of chilled water and 130,000 lbs/hr of steam, respectively. The central steam plant is equipped with two 1950's vintage 40,000 lb/hr natural gas & No. 2 oil boilers and two newer 20,000 lb/hr fire-tube boiler, plus a few smaller boilers in a satellite plant. 6 centrifugal chillers are spread across 2 CHW plants (North and South).

System Capacity

District Heating (steam)	130,000 lbs/hr
District Cooling (chilled water)	6,000 tons

System Single Line Diagram



To view this diagram in a web browser, please visit:
https://www.districtenergy.org/home/reports/wake-forest

System Performance

1. **System Efficiency**
   - CHW: .78 kW/ton pre-improvement, .54 kW/ton after
   - Boiler efficiency: 75.6% before improvement, 80.3% after
   - Steam out gas in: 75.6% pre 80.3% post-renovation
2. **System Reliability**
3. **TES Reducing Peak Demand - NA**
4. **Improved CHW delta T**
   - Before improvement 7-8, 10F after

Technical Best Practices

1) Optimize Campus EUI as First Step of Decarbonization

In 2014, WFU partnered with an engineering consulting firm to evaluate opportunities to improve the emissions and efficiency of the chilled water system. University Leadership has committed to reducing its carbon emissions, and, rather than investing in new technology, has elected to optimize and improve its existing infrastructure to maximize the environmental and energy savings while waiting for more advanced technology to come to market.

a. Existing system optimization & building-side improvements

The first year of the project was devoted optimization, designed to squeeze as much capacity out of the existing CHW system as possible and start to realize some of the short-term economic benefits for minimal capital investment. The first step was collecting and baselining the data coming out of the new optimization system, allowing the utilities team to identify low deltaT buildings and other issues for the first time. Based on this data, they started making targeted improvements, including closing bypasses, installing Belimo energy valves to improve building deltaT, replacing residential fan coils, and upgrading air handlers. The team began with the worst performing buildings and worked their way up through the list, using the optimization system to validate the performance of the interventions. One strategy was to reduce pumping to sections of the loop they suspected were particularly inefficient until we observed temperature delivery issues and target the most impacted buildings first.

b. Chilled water improvements

Once the optimization system and first wave of building-side improvements were in place, the campus spent 2 years monitoring the optimization system, and after engineering analysis concluded that, though they had already achieved significant energy savings, the system would require additional renewal and capacity improvements to meet the growing cooling load.

The improvement program included

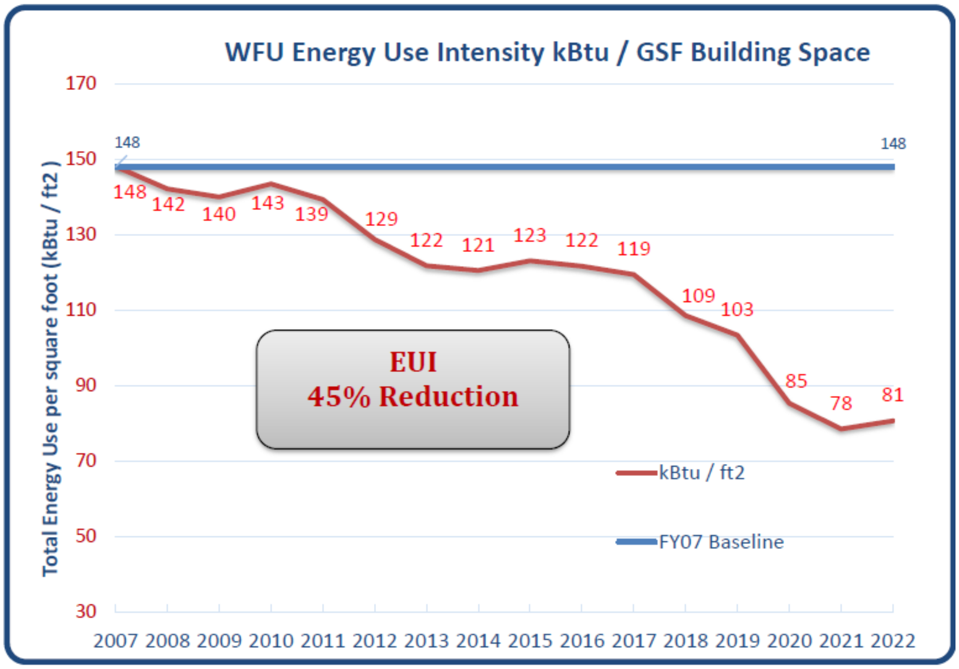
- Decommissioning the 2 smaller CHW plants
- Upgrading the South Pant
- Replacing and expanding the North Plant
- Maintaining optimization protocols throughout

Both the north and south plants were converted from primary secondary to variable primary CHW, with variable CHW pumps. The North Plant's capacity was doubled from 1200 to 2400 tons, converted to headered variable CHW pumping, and, once the pumps were moved outside, VFD chillers were added. Pressure sensors were also added to identify and address areas of distribution with poor flow. When the revitalized North plant came online, the utilities team saw the CHW system efficiency improve by 16% over the legacy system. Installing optimization controls in both plants has improved the combined efficiency by nearly 25%, and the combination of improved plant efficiency and decreased cooling load has decreased the campus electricity consumption by nearly 5%.

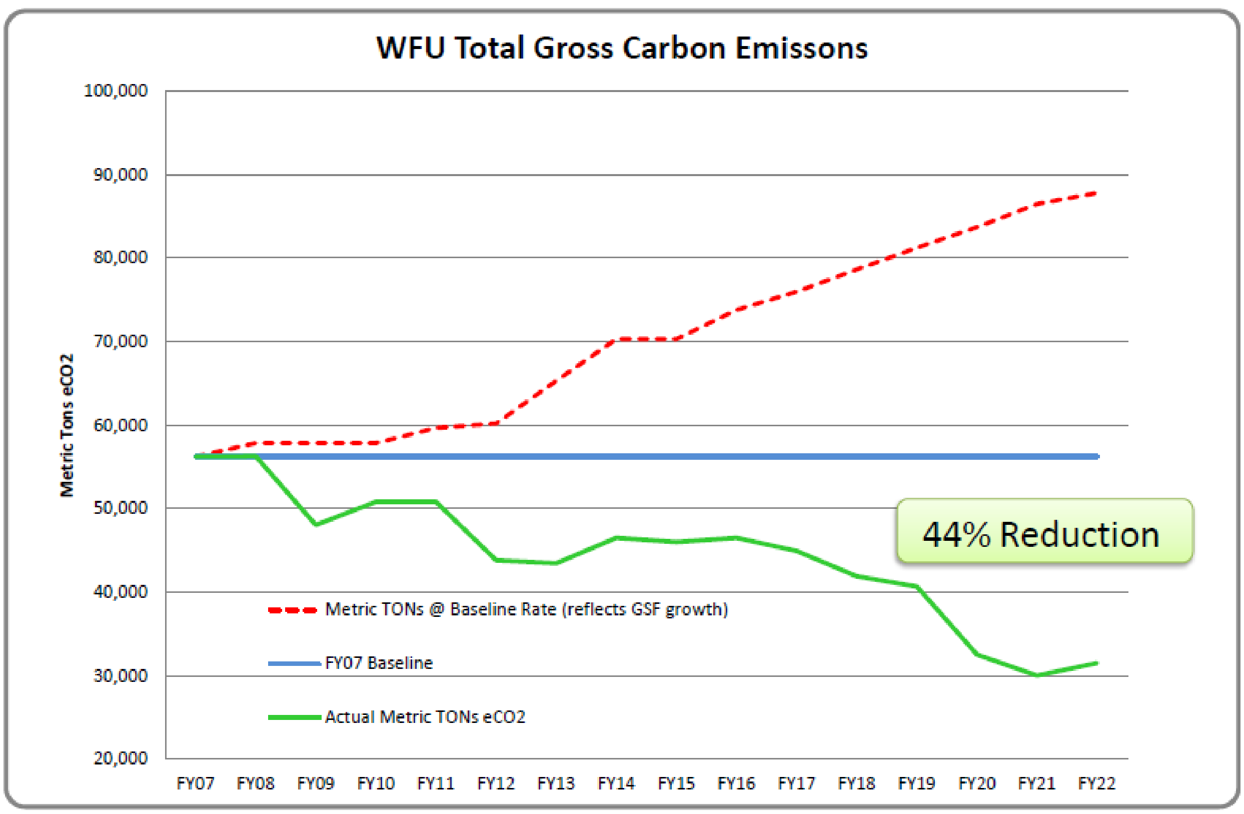
Between the ongoing building-side efficiency measures, larger CHW improvements, HVAC upgrades and other campus energy projects, WFU has dropped the campus EUI (kBTU/SF/yr) from 148 in 2007 to 81 in 2022, even as campus square footage has grown.

The first year of the project was devoted optimization, designed to squeeze as much capacity out of the existing CHW system as possible and start to realize some of the short-term economic benefits for minimal capital investment. The first step was collecting and baselining the data coming out of the new optimization system, allowing the utilities team to identify low delta T buildings and other issues for the first time. Based on this data, they started making targeted improvements, including closing bypasses, installing Belimo energy valves to improve building delta T, replacing residential fan coils, and upgrading air handlers. The team began with the worst performing buildings and worked their way up through the list, using the optimization system to validate the performance of the interventions. One strategy was to reduce pumping to sections of the loop they suspected were particularly inefficient until we observed temperature delivery issues and target the most impacted buildings first.

Wake Forest University Energy Use Intensity - 2022



Wake Forest University Gross Carbon Emissions - 2022



2) Steam system upgrades

Like the CHW program, in 2012 WFU partnered with the same engineering firm to assess the current and projected steam needs of the campus. The key goals of the project included reducing emissions, improving energy efficiency, increasing capacity, and bolstering reliability.

As was the case for CHW, the firm began with benchmarking – they created a steam profile for 2011 and projected it out 5 years, assuming full campus buildout. This data helped the team understand that the 2 existing 50s vintage boilers were operating below their ideal firing rage for most of the year, and while peak loads would increase over time, summer and shoulder season loads would not.

An older master plan anticipated adding another 50,000 lbs/hr boiler to the plant, but the team determined that a smaller, incrementally sized boiler would better handle the higher peak load while operating efficiently during low- to moderate-load periods. Two 20,700 lbs/hr boilers were selected including feed water and condensing economizers, and the first was installed in 2013. The 2nd was added in 2019.

To support the new boiler, the team completed renewal projects on the smaller ancillary systems, including installation of a new full-sized deaerator, condensate surge tank, condensate pumps, and feed water pumps. Customized wet-layup and operational techniques were developed to maintain reliability of redundant systems, and the offline deaerator would be kept warm using recovered flash steam. Both condensate tanks would be kept in service using a piped equalizer connection & staged makeup water control system. Condensate return monitoring also added which allows timely discovery of issues on campus.

Because the team opted for smaller boilers, they were able to invest in fully metered combustion controls with oxygen trim, flash system recovery, continuous blow-down heat exchanger and in a flue gas heat recovery system. The year it was installed, the new boiler averaged 86% fuel to steam efficiency while the two existing models averaged only 75%.

Management Best Practices

1) Utilities Integration into Centralized Scheduling Platform

In the last few years, WFU has integrated the utilities team into a centralized classroom scheduling system that has helped the group more efficiently manage building energy use. Previously, building automation systems were run on a series of assumptions: generally, classes are scheduled M-F, 9 AM – 5 PM, very few classes are scheduled in classrooms on weekends, etc. Additionally, buildings like libraries were kept "on" 24/7, assuming full-time occupation. Establishing the centralized scheduling system allowed the utilities team to check and adjust these assumptions, as they found that classes are often scheduled outside of regular hours, and many classrooms are left empty on Fridays, amongst other things. By cross-checking the scheduling software with building occupancy sensors, they're able to rapidly bring buildings on- or off-line or put them on standby. This was particularly valuable at the beginning of the COVID-19 pandemic, when the campus pivoted to virtual learning, as they were able to shut down over most of the campus within 2 weeks, rather than the 2-3 months it would have taken previously.