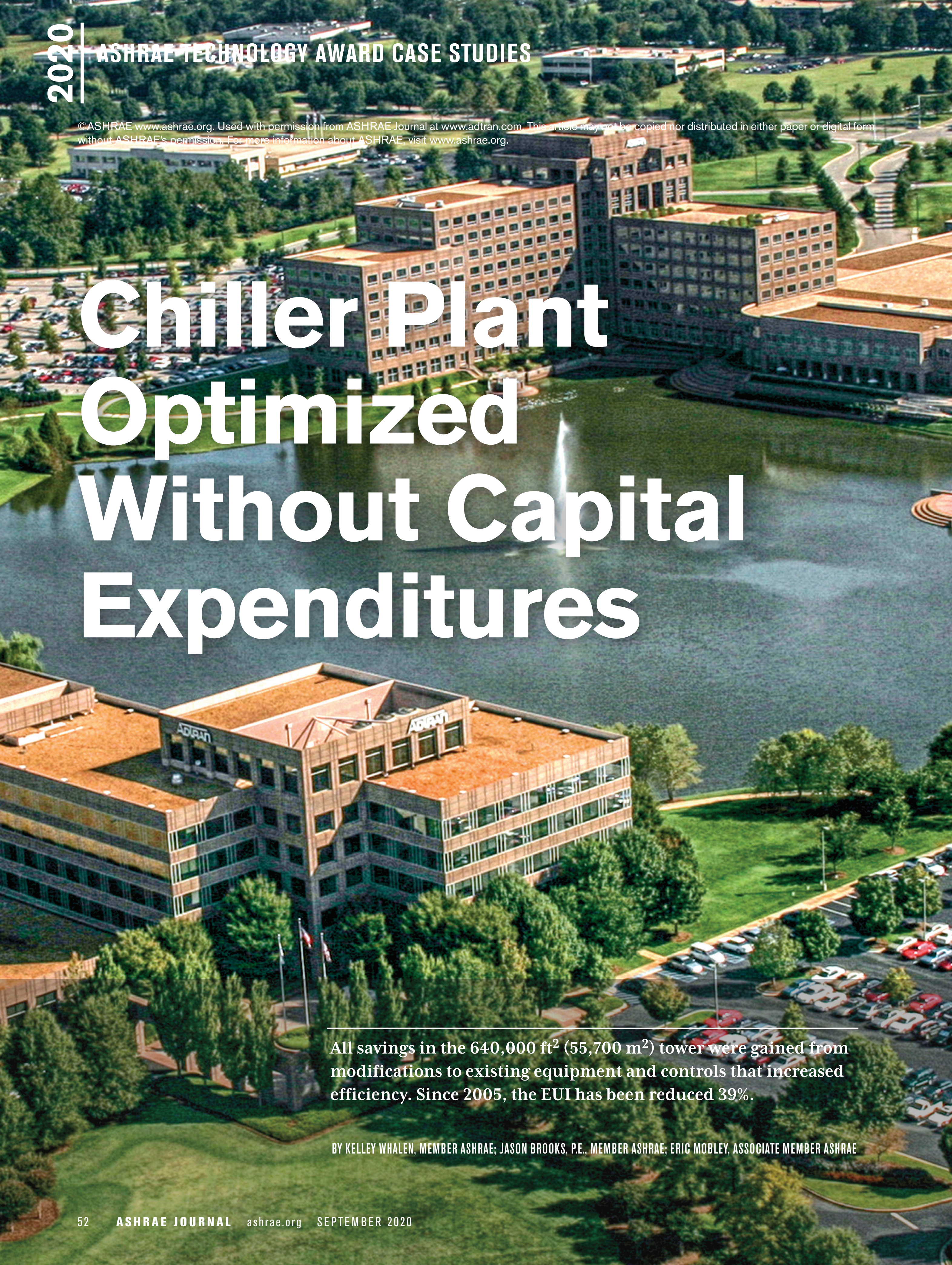

Chiller Plant Optimized Without Capital Expenditures

All savings in the 640,000 ft^2 (55,700 m^2) tower were gained from modifications to existing equipment and controls that increased efficiency. Since 2005, the EUI has been reduced 39%.

BY KELLEY WHALEN, MEMBER ASHRAE; JASON BROOKS, P.E., MEMBER ASHRAE; ERIC MOBLEY, ASSOCIATE MEMBER ASHRAE

The ADTRAN East Tower in Huntsville, Ala., used several optimization methods to radically reduce energy use without costly equipment replacements. The project was completed without any capital expenditures; all results were gained strictly from modifications to the existing equipment and controls to increase efficiency. These methods saved over $71,326 annually in energy costs with a simple payback of 1.86 years.

The chiller plant consists of three 440 ton (1547 kW) chillers, three 490 ton (1723 kW) cooling towers, three constant volume chilled water pumps, three condenser constant water pumps, two heat exchangers, four auxiliary pumps, and one water heater.

Energy Efficiency

At the beginning of the project, ADTRAN was consuming 28,390,000 kWh annually on a campus level, which is comprised of three towers that occupy 1.04 million ft^2 (96 619 m^2). The East Tower, which accounts for 640,000 ft^2 (59 458 m^2) of the total footprint (slightly over 60%) consumes about 60% of that total use. Changes implemented in this project are saving ADTRAN over 950,000 kWh annually in energy consumption from just targeting the chilled water plant that serves the East Tower.

The savings are based on measurement and verification of data gathered over several years of building automation system (BAS) data and actual power meter data from ADTRAN and the engineering company's power loggers for over 10 months. Using regression analysis and engineering calculations on trended and measured data, savings were determined (see Cost Effectiveness section).

In addition to these savings, changes have been implemented, achieving the following:

- Increased business continuity from changes that make it unnecessary for ADTRAN to run more than two chillers, which also creates another layer of redundancy in the system if a chiller goes down.
- Proper cooling of the East Tower D-Wing, which has historically had issues with cooling, through changing the system to allow more water flow.

Given that this project was completed without any capital expenditures, all results were gained strictly

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Building at a Glance

ADTRAN East Tower

Chilled Water System Optimization

Location: Huntsville, Ala.

Owner: ADTRAN

Principal Use: Office building, laboratory spaces, data centers, electronics testing

Gross Square Feet: 640,000

Conditioned Square Feet: 640,000

Substantial Completion/Occupancy: December 2018 from modifications to the existing equipment and controls that increased efficiency.

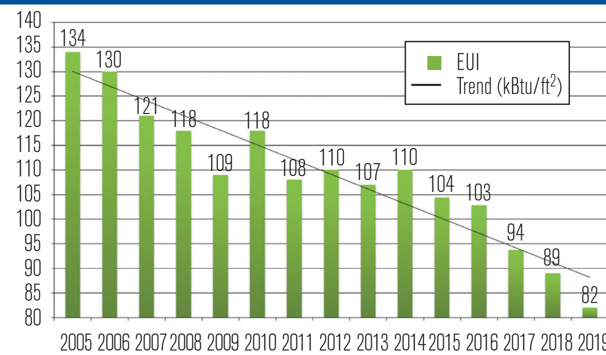
Existing Operation Before This Retrocommissioning Project

In 2005, ADTRAN created an energy program, and since then hundreds of ECMs and many retrocommissioning (RCx) projects had already taken care of the low-hanging fruit.

Below are highlights of activities that took place under this retrocommissioning project:

- Trended over 300 points pertaining to the plant in one-minute time intervals, capturing over 131 million readings using the BAS, which aided in analysis of the plant's current operation and aided in monitoring as changes were made.
- Installed four power loggers/analyzers capturing over two million power consumption readings over 10 months. This data is used for measurement and verification of savings calculations. Virtually all the equipment in the building was monitored including chillers, pumps, cooling towers and air-handlers. Space temperatures and water temperatures are also trended.
- Developed equations to calculate plant energy use for individual equipment and total plant energy consumption, which allowed for the modeling of the plant's energy use to aid in decision-making and savings calculations. These equations were developed using regression analysis of power data from the loggers versus an independent variable (such as speed for pumps) from the BAS.
- Performed functional testing, evaluated all existing plant programming, monitored the chilled water system and reviewed several years of historical building data.
- Modified chilled water flow and condenser water flow to maximize the amount of cooling capacity delivered to air-handling units with the highest cooling demand, which allowed those units to meet their cooling demand, a feat the units previously could not achieve.
- Simulated the building and chiller plant in multiple iterations of models with various configurations to help visualize the effects that various changes would have on the system.
- Developed new energy saving sequences of operation by reprogramming 30 inefficient existing programs while measuring the actual plant energy consumption reductions.
- Modified control setpoints so they are automatically calculated based on real-time building inputs received from the building automation system, allowing the system to have better response times to changing building conditions.

FIGURE 1 EUI history.



Since 2005 baseline, EUI has been reduced 39%. (Revised 1/8/20)

- Tested all new programming through various scenarios, temperatures, flows, modes of operation and building loads to ensure that the sequences would work across all situations.

As this project was specific to the East Tower, the following descriptions detail the previous operation of some of the key pieces of equipment and the associated changes made to them.

- **Chiller Operation.** If the chilled water supply temperature (CHWST) got 2.5°F (1.38°C) above the CHWST setpoint of 38°F (3.3°C) for 30 minutes, an additional chiller is enabled and starts until the difference between the CHWST and chilled water return temperatures (CHWRT) gets below the setpoint. The chiller add sequence was modified so that the ΔT required for another chiller to come on varies with time of day (see Innovation section). A CHWST reset was also added based off building load. A reset was programmed previously, but it was not able to operate correctly due to the decreased flow from the chillers. This was rectified in this project.
- **Cooling Tower Operation.** The cooling towers were staged so that once one of them reached its max speed, the next tower would turn on and ramp up. The condenser water setpoint was set to 78°F (25.5°C). The cooling towers staging was modified so they ramp together to take advantage of the power savings associated with the fan laws. The condenser water setpoint was programmed to track the wet-bulb temperature with an offset so that the cooling towers would output the coldest water possible to increase the efficiency of the chillers.
- **Heat Exchanger (HX) 2 operation.** The auxiliary

pumps for the HX2 and self-contained unit (SCU) loop, used to run continuously without regard for if the HX2 leaving water temperature was below its setpoint. Pump 8 operation was changed to have a minimum speed of 15%. The programming was changed to shut the pump off if the leaving water temperature from HX2 dropped 10°F (5.5°C) below its setpoint. Pump 8 will not cut on again until the HX2 leaving water temperature raises 5°F (2.7°C) above its setpoint. Pump 10 operation was changed so that it runs at a constant 20% instead of 35%.


The East Tower chiller plant.

- **HX1 operation.** Used only when the chiller plant has the waterside economizer mode enabled, which occurs when the outside air temperature is below waterside economizer mode enabled setpoint. Once the waterside economizer is enabled, the chillers are shut off and isolation valves on the condenser and chilled water side close to isolate the chillers. Next, the cooling tower fans ramp to a speed of 100%. The cooling tower attempts to produce condenser water at temperatures of near 35°F (1.6°C). With the changes made to the airside economizer operation, the plant can stay inside waterside economizer mode for much longer stretches of time.
- **Airside Economizer Operation.** See indoor air quality section.

Indoor Air Quality

The original operation of the air handlers would allow for the units to go into economizer mode if it was Monday through Friday between 7 a.m. and 5 p.m. and the air handler was in cooling mode with a return air dew-point temperature greater than the outside air dew-point temperature but less than 50°F (10°C), outside air dry-bulb between 65°F (18.3°C) and 40°F (4.4°C) and the chilled water valve greater than 10% open. The updated sequence was modified to allow for airside economizer operation if the air handler is occupied and in airside economizer mode, regardless of time of day and day of week, and the outside air dry bulb is less than 68°F (20°C).

In addition, instead of having the air handler come out of economizer mode when the outside air temperature is below 40°F (4.4°C), the sequence was modified so that the outside air damper for the unit would modulate closed as the discharge air temperature dropped below its setpoint.

These programming modifications allows an additional 45,000 cfm (21 238 L/s) of cool outside air, which will reduce CO_2 levels and increase indoor air quality during early morning operation of the building.

See the Maintenance and Operation section for discussion on occupant comfort.

Innovation

To address the single setpoint that added a chiller regardless of time of day or day of the week, the add sequence was changed to take into account the load pattern throughout the day. From *Figure 2*, it is observed that the load of the building varies throughout the day.

Monday thru Friday 4 a.m. to 8 a.m.: A second chiller will be added if the CHWST exceeds the chilled water supply setpoint by 3.5°F (1.9°C), the third at 7.0°F (3.9°C). The time from 4 a.m. to 8 a.m. shows a sharp increase in the rate of change of the building load due to equipment turning on (*Figure 2*).

Monday thru Friday 8 a.m. to 5 p.m: A second chiller will be added if the CHWST exceeds the chilled water supply setpoint by 4.5°F (2.5°C), the third at 7.5°F (4.1°C). The time from 7 a.m. to 5 p.m. shows a gradual increase in the rate of change. This is partly due to the typically increasing outside air temperature.

All other times: A second chiller will be added if the CHWST exceeds the chilled water supply setpoint by 6.5°F (3.6°C) the third at 8.5°F (4.7°C). These times were observed to be the lowest load times and the most constant load times.

Maintenance and Operation

Preventing the second chiller and third chiller from coming on not only significantly reduces energy cost, it also reduces the run hours, operations and maintenance cost, extending the life of the chillers by several years. Due to the cost of a chiller being approximately $1 million each, extending the life of the chiller plant postpones this investment for several years.

Other O&M savings are from the reduced number of work orders, many of which were from the facility having cold and hot spots. After all measures were implemented, the amount of work orders was reduced by nearly 50% from an average of 80 work orders per year for 2015, 2016, and 2017 to 47 work orders in 2018. This allows additional time for the staff to perform preventative maintenance, which further helps with operations and occupant comfort.

During this process, trends and reports were created for all the equipment in the plant, which have continued to be available to the staff. These trends and reports aid ADTRAN in analytics and diagnostics of equipment conditions.

FIGURE 2 Building load.

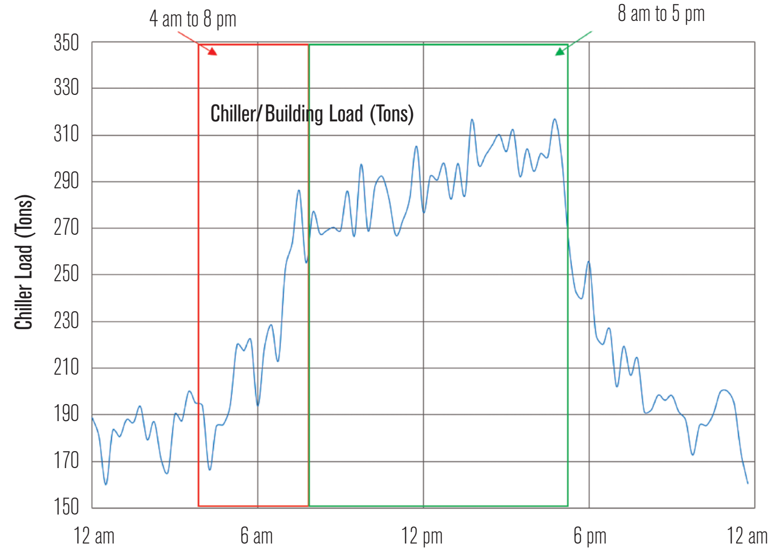


TABLE 1 Total savings.

TASK	ANNUAL COST SAVINGS ($)	ENERGY SAVINGS (KWH)
Chiller Plant/Waterside Equipment Optimization	$33,101	441,347
Airside Equipment Modifications	$38,225	509,660
Annual Savings for this Project	$71,326	951,007

Cost Effectiveness

Implemented changes are saving ADTRAN over $71,326 annually in energy costs with a simple payback of 1.86 years based off on a project cost of $133,000.

In addition to these savings, other implemented changes have achieved a cost avoidance equal to approximately $1 million from not having to buy a fourth chiller since only two chillers are required. *Table 1* details the total savings.

Environmental Impact

All reduction of global climate change gases (i.e. carbon dioxide emissions), elimination of CFCs, reduction in waste discharge and other environmentally favorable items has been calculated using the United States Environmental Protection Agency (EPA) Greenhouse Gas Equivalence Calculator. The calculation is based on a 950,000 kWh reduction. The calculator can be found at https://tinyurl.com/j3glbf8.

Greenhouse Gas Emissions

- 143 passenger vehicles driven for one year.
- 1,642,527 miles (2 643 390 km) driven by an average passenger vehicle.

CO_2 Emissions

- 75,593 gallons (286 151 L) of gasoline consumed.
- 65,991 gallons (249 803 L) of diesel consumed.
- 734,422 pounds (333 128 kg) of coal burned.
- 8.9 tanker trucks' worth of gasoline.
- 80.4 homes' energy use for one year.
- 117 homes' electricity use for one year.
- 3.7 railcars' worth of coal burned.
- 1,555 barrels of oil (247 225 L) consumed.
- 85,661,940 number of smartphones charged.

Greenhouse Gas Emissions Avoided

- 234 tons (212 281 kg) of waste recycled instead of landfilled.
- 33.5 garbage trucks of waste recycled instead of landfilled.
- 29,312 trash bags of waste recycled. ■

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