The Blake R. Van Leer building at Georgia Tech in Atlanta was the site of a real-time pricing pilot project.

BACnet® at Georgia Tech

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Large facility owners generally negotiate yearly or multiyear electric service agreements and often are given lower base rates in exchange for sharing the risk of price fluctuations. This agreement may take the form of a capped rate, or may go as far as a real-time market rate where the facility owner sees every price spike in the electric market. Price spikes due to normal summer heat, as well as unforeseen events such as power plant emergency shutdowns, occasionally can reach five times the base utility rate, or higher. The challenge for the facility owner is how to reduce power consumption during periods of peak pricing, while maintaining mission critical building loads.

This article presents an automated load shedding strategy implemented at the Georgia Institute of Technology (Georgia Tech). The strategy involved increasing space temperature heating and cooling offsets, performed automatically in response to the electric real-time

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price (RTP) reaching a certain level—the RTP setback price. Temperatures are allowed to drift between heating and cooling offsets. Upon reaching the RTP setback price, the heating and cooling offsets moved from the normal ±1°C (±2°F) operating limits to a ±3°C (±5°F) RTP setback condition.

A pilot project at Georgia Tech was conducted as part of the ASHRAE Standing Standards Project Committee 135 BACnet Utility Integration Working Group's (UI-WG) efforts to implement standard methods for load shedding. The larger UI-WG goal is to provide standard methods for communication with utilities and providing tools for facility owners to enable different forms of demand reduction. The pilot project was conducted during the latter half of the 2006 cooling season. Based on the results of the pilot project, it is estimated that using this strategy for the full Georgia Tech campus cooling season would result in a $150,000 annual electric cost savings. The method presented here can be used by other facility owners to evaluate automated demand reduction in conjunction with different utility demand reduction and real-time pricing programs. A review of different demand reduction strategies in buildings can be found in Reference 1.

Georgia Tech Facilities

Georgia Tech is a research-driven institution and has many research laboratories for which temperature limits are critical and fixed. The Facilities Department at Georgia Tech has participated in the Georgia Power Company/Southern Company's hour-ahead, real-time rate program for several years. Due to the stringent space temperature requirements of the research facilities, there had been no organized program for reducing power consumption during price spikes. Georgia Tech recognized that some noncritical spaces were available for load shedding: public space, classrooms, conference rooms and offices.

Part of Georgia Tech's initial conservation strategy was to implement night setback temperature offsets for noncritical spaces. As part of the pilot project planning phase, Georgia Tech's facilities area managers consulted with occupants to determine which spaces could be considered noncritical for temperature control. The facilities department performed thermal modeling of buildings using DOE-2 to study recovery time effects, and selected a ±5°C (±9°F) night setback condition on space temperatures in all noncritical spaces campuswide. This laid the foundation for applying a RTP temperature setback strategy. With rising electric rates, the Facilities Department was looking for ways to take action when price peaks were in effect. Historically, Georgia Tech has seen a price spike exceeding $3/kWh, with spikes 10 times the base rate more common. The pilot project was performed to study the effectiveness of using space temperature setpoint adjustments in noncritical spaces for load curtailment during times of peak pricing.

RTP Setback Pilot Project

In preparation for the summer 2006 cooling season, Georgia Tech's facilities department planned a pilot project to test a space temperature offset setback strategy that was triggered by electrical cost. The goal was to shave peak energy use by reducing the building cooling load in noncritical spaces during times of peak electrical rates. Georgia Tech worked together with Southern Company and a controls manufacturer to set up an automated real-time price connection to a building control Web server. With this interface, automated load shedding is activated when the RTP rate rises above a certain trigger level. The study period ran from July to September 2006. RTP curtailment events were observed only in July and August.

The pilot project was implemented using the Blake R. Van Leer building, a noncritical, nonresearch building. The Van Leer building is the main building for electrical engineering instruction, and is a 1950s era building. This building was selected because it has a number of different rooms and work areas, each with different thermal load demands. The building HVAC system had been recently renovated and, as part of the renovation, was re-instrumented with sensors that could be used to obtain accurate zone temperature measurements.

Five zones in the Van Leer building were studied in the pilot project: a 5 m × 12 m (15 ft × 40 ft) office space (office); a 3 m × 12 m (10 ft × 40 ft) reception area with several open adjoining rooms (reception); a 15 m × 15 m (50 ft × 50 ft) classroom (classroom); a 12 m × 12 m (40 ft × 40 ft) electronics teaching laboratory (lab); and a third floor corridor (corridor) which has as its south wall a largely shaded glass exterior window.

RTP Interface

The HVAC system is a direct digital control system. As part of the project, the controls manufacturer worked with Georgia Tech to interface its control system to the Southern Company's RTP database via a building automation central server to continuously read and record real-time prices. The utility price data is available as price estimates 48 hours ahead (24 price/hour pairs for today and 24 price/hour pairs for tomorrow) with fixed prices 65 minutes ahead and 125 minutes ahead. For example, fixed prices for the 1 p.m. to 2 p.m. window are first released at 10:55 a.m. This data is downloaded to a database and archived in tables by a structured query language (SQL) server. The controls system is programmed so that when the price level for the coming two hours exceeds a preset trigger level then the RTP setback logic is activated. The setback logic overrides default room heating and cooling offsets, changing values from the normal ±1°C (±2°F) to a wider ±3°C (±5°F). When the price falls back below the trigger value, the offsets are reset to default values.

An application program written by the controls manufacturer in accordance to Georgia Tech specifications runs on the central server and allows Georgia Tech to monitor and respond to the real-time energy prices provided by the Southern Company. The application connects to the Southern Company's Web site to obtain current and forecasted hourly rates in an extensible markup language (XML) format. Those rates are written to 24 BACnet analog value (AV) objects in the controller, allowing the system to reduce the electrical demand based on user-specified price thresholds. The real-time pricing interface is shown in *Figure 1*.

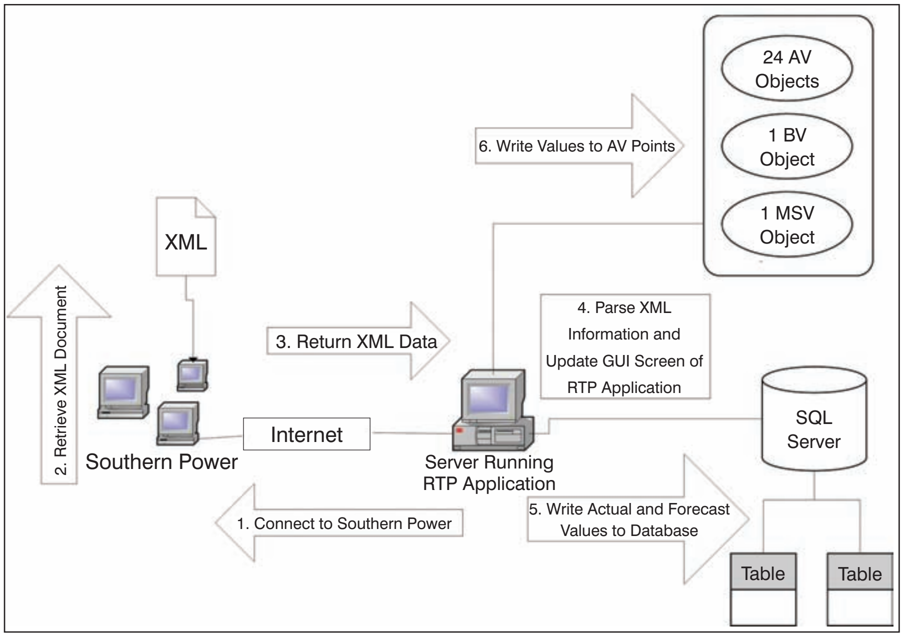

Figure 1: Real-time price interface functional diagram.

RTP Setback Pilot Results

Temperature profile characteristics in the five test spaces in the Van Leer building (office, reception, classroom, lab and corridor) showed expected daily periodic profiles. These profiles generally stayed within the set temperature bands with temperatures floating up at night during the night setback hours, and then brought back into control each morning. An example of several of the monitored space temperatures are shown in *Figure 2* where the office, lab and reception areas temperatures are seen to drop at 7 a.m. with the change from nighttime ±5°C (±9°F) setback to the daytime ±1°C (±2°F) setback, with 21°C (70°F) as the baseline temperature. At approximately 2 p.m. on these three days the control system goes to the RTP ±3°C (±5°F) setback. In each case the temperatures are seen to increase above the previous 22°C (72°F) cooling offset. Although the lab temperature is seen to fluctuate considerably, it clearly jumps to a new level after onset of the RTP setback. Although the reception area temperature drops slowly throughout the morning without reaching the daytime cooling setpoint, it also clearly rises with the onset of RTP setback. These trends are as expected and show a rise in temperatures when RTP setback is initiated.

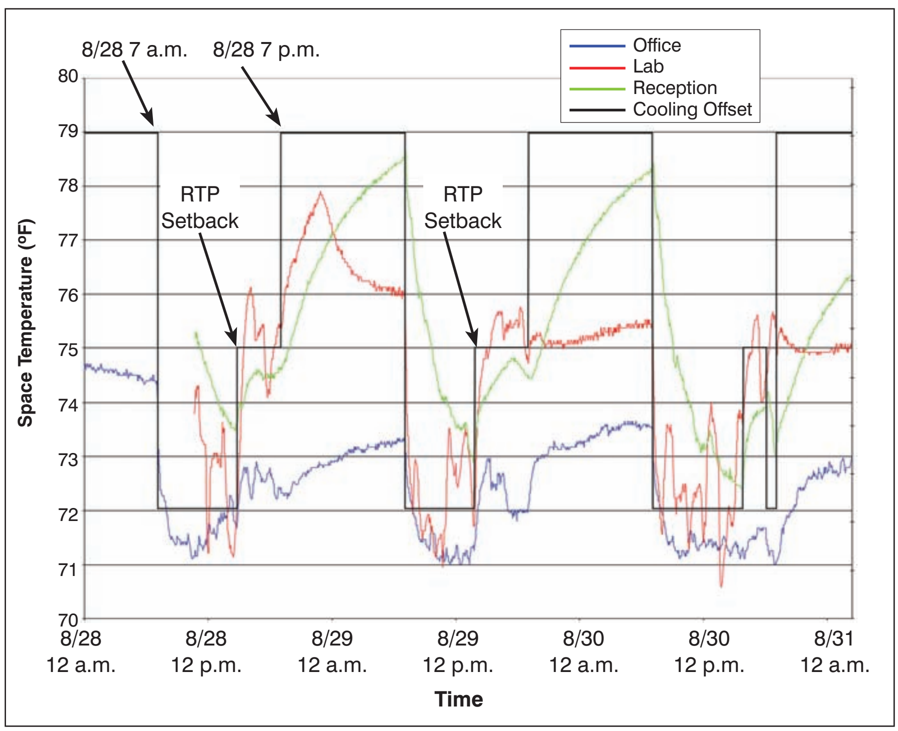

Figure 2: Van Leer space temperatures, Aug 28–30, 2006. Some data were unavailable (initial points on lab and reception area traces).

Some unexpected results led to the conclusion that different spaces will respond differently to changes in setpoints:

- The corridor space was not under control and is the return air path for the system. The mean temperature remained above the cooling setpoint temperature with no response to RTP setback changes.
- The classroom saw a counterintuitive response during periods when classes were not in session, with temperature decreasing when classes were not in session, independent of cooling setpoint.

The classroom's decreasing temperature merits discussion. The minimum requirement for outdoor air in the room is set based on a fully occupied room. This leads to a drop in temperature or overcooling when the room is not at maximum occupancy, and to cold complaints from students. Strategies to monitor the actual number of persons in the room and include this in the setpoint control strategy are being considered for correction of this occurrence.

Maintaining occupant comfort, as well as clear communication with the affected staff, is important for any program. A significant effort was made to educate the facilities staff and occupants about the program. Georgia Tech uses an area management organization dividing the campus into six managed areas to provide direct contact with the occupants of the building. The area managers discussed the proposed energy saving strategy with each organization in the area buildings. Occupant support for this new energy strategy was close to 100%.

Occupants were informed of the program goals and details, but they were not informed of specific events. Only the facility managers were informed of pending RTP temperature setback events (45 and 15 minutes ahead).

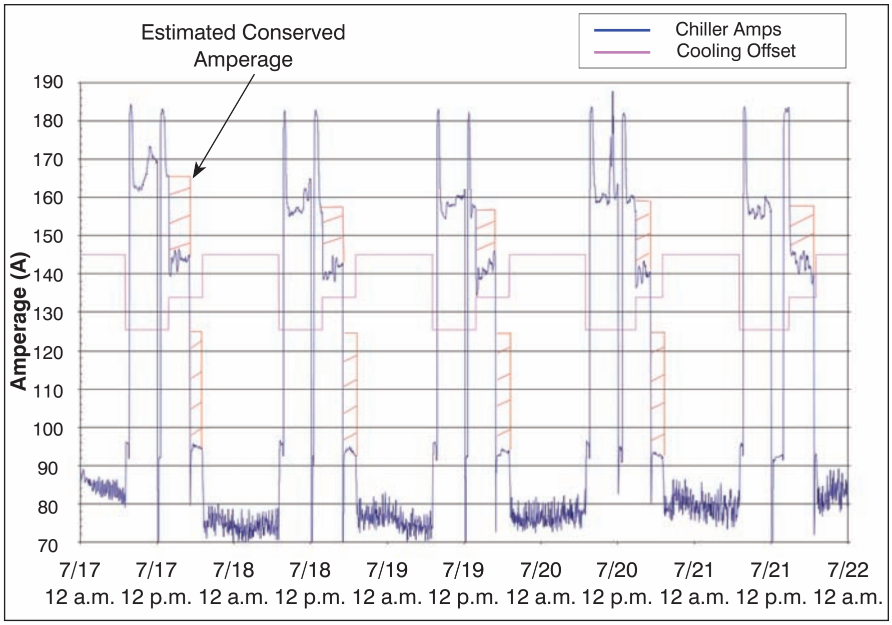

Figure 3: Chiller amperage showing estimated energy savings (hatched).

Energy and Cost Savings Analysis

The energy and cost savings due to RTP curtailment depend on the frequency of RTP events and the degree of power reduction during those events. RTP event frequency depends on the user's trip point (RTP setback price) and the utility's real-time price. For the Georgia Tech tests, chiller power across the setback period was used to estimate power savings, and historical price and weather data were analyzed to estimate the number of events occurring outside the pilot time period.

Power reduction was estimated by observing the typical chiller power (amperage) profile during the period when RTP setback was not implemented and comparing it to the reduced profile when RTP curtailment occurred. We noted in our study that chiller power would drop off to nighttime levels at approximately 6 p.m. This observation was consistent with the building occupancy level. *Figure 3* shows the difference (crosshatched) between estimated chiller amperage without curtailment and the recorded amperage during curtailment. Assuming the chillers operate continuously at their rated voltage, the chiller power can be calculated directly from the chiller current, and then the energy savings can be calculated.

Estimated energy savings for each curtailment event were totaled over the weeks of the test period and are given in *Table 1*. Cost savings were estimated assuming that peak energy reductions are shifted to night hours when electric rates are lowest, after some hours of night setback and riding the thermal mass of the building. Shifting loads off peak provides other benefits—one study[2] reported a 15% chiller efficiency gain with daytime to nighttime outdoor temperature differential of 11°C (20°F). If night temperatures are low enough, additional savings may be possible using economizer mode. However, if the night is hot and humid, it is also possible that building temperatures will climb up to the nighttime cooling setpoint before electric rates drop to the lowest rate so cost savings are reduced. Cost savings in *Table 1* were estimated as the energy savings multiplied by the differential of the average price for electricity during the curtailment periods ($0.146/kWh) and the nighttime electric rate. Based on this cost savings estimate we achieved a savings of $790 during 15 curtailment events in the Van Leer building. These 15 curtailment events cover 71 hours in RTP setback.

Week	Number of RTP Events	Amp-Hours Saved	Energy Saved (kWh)	Cost Savings ($)
July 16–21*	5	524	3772	438
Aug. 8–12	4	185	1335	155
Aug. 13–19	2	27	195	22
Aug. 20–26	1	60	431	50
Aug. 27–Sep. 2	3	150	1080	126
Total	15	946	6813	790

*July 22–August 8 data not available

Table 1: Summary of energy and cost savings.

For the purposes of extrapolating the Van Leer building data to the entire campus, we assume the Van Leer building energy savings will be similar to other office/classroom buildings on campus and proceed to calculate a power savings density ($kWh/m^2 \cdot h$). The Van Leer building covers a total 13 000 gross m^2 (140,000 gross ft^2) of which only 9300 m^2 (100,000 ft^2) is controlled space (noncritical space where setback is allowed). Excluded space includes some laboratory areas and utility areas. From *Table 1* we see that total estimated energy saved during the measured period was 6,813 kWh, which was achieved in the 9300 m^2 of noncritical space during the 71 hours of RTP setback. This gives us an estimate for the power savings density (PSD):

$$\text{PSD [kWh/(m}^2\cdot\text{h)]} = \text{Est. Energy Savings (kWh)/} \\ \text{[Controlled Space (m}^2\text{)} \times \text{Setback Hours (h)]} \qquad (1)$$

The numbers above gives a PSD equal to 0.0103 $\text{kWh/m}^2\cdot\text{h}$ (9.6×10^{-4} $\text{kWh/ft}^2\cdot\text{h}$). We can then multiply this value by the total campuswide controlled space, the total number of expected hours in RTP setback for a cooling season, and by the cost differential during RTP setback events to get projected campus yearly cost savings using this method.

$$\text{Projected Savings (\$/yr)} = \text{PSD (kWh/m}^2\cdot\text{h)} \times \\ \text{Total Controlled Space (m}^2\text{)} \times \text{Est. Setback Hours (h/yr)} \times \\ \text{Price Differential (\$/kWh)} \qquad (2)$$

where Price Differential is taken as the difference between the average price for electricity during the curtailment periods and the nighttime electric rate.

Generalized Cost Savings Estimation

The following generalized approach to estimating cost savings and establishing the RTP setback approach is suggested. The most difficult parameter to find is an estimate of the power savings density for a given facility or campus. As a rough estimate, a facility manager may begin with the PSD found in the Van Leer pilot tests. However, it must be understood that the PSD will be sensitive to building construction, HVAC system and RTP setback strategy. The main characteristics of the setback strategy used at Georgia Tech are that temperature offsets were moved from ±1°C (±2°F) to a wider ±3°C (±5°F) RTP setback to ±5°C (±9°F) night setback, and that the price point was selected so that RTP setback occurred on most days with a mean afternoon temperature greater than approximately 28°C (82°F), which corresponded to a setback price of approximately four times the normal off-peak rates. To implement this strategy, the local utility needs to offer an RTP rate plan and the facility owner needs access to historical price data.

The generalized procedure for initializing the RTP setback approach is as follows:

1. Run a pilot test to:
   - Establish the process of:
     - identifying noncritical spaces,
     - communicating with occupants and building managers,
     - data collection and analysis, and
     - requirements of control system reconfiguration, etc.
   - Calculate a power savings density estimate for a representative building or set of buildings, as in *Equation 1*.
2. Look at historical electric rate data, and for a given cooling season and given setback price:
   - Determine the number of RTP setback events that would have occurred, the average length (hours) of each RTP setback event and the total number of hours in RTP setback.
   - Calculate the average electric price over the hours in RTP setback.
3. Apply campus data, price data, and hours in setback to *Equation 2* to find estimate of campuswide yearly savings.

Another useful way of looking at the data is to correlate price to outdoor temperature for the current year. This is shown in *Figure 4* for the 2006 Georgia Tech study. This figure shows the price distribution and allows estimation of price as a function of outdoor temperature. A vertical line is drawn at the intersection of the curve fit to the $0.10/kWh chosen setback price, showing a corresponding mean afternoon temperature of approximately 28°C (82°F). On days with a mean afternoon temperature above 28°C (82°F) an RTP event is expected. This baseline temperature allows analysis of previous year temperature data to estimate variation in RTP setback events year to year (due to warmer or cooler summers).

Georgia Tech has 840 000 gross m^2 (9 million gross ft^2) of building space, of which about 62% is considered critical temperature research space or other areas to which the energy setbacks cannot be applied, leaving approximately 320 000 m^2 (3.4 million ft^2) of noncritical space for RTP setback purposes. Applying *Equation 2* to the above numbers:

$$\text{Projected Savings [\$/yr]} = .0103 \text{ [kWh/(m}^2\cdot\text{h)]} \times \\ 20000 \text{ (m}^2\text{)} \times [(84 \text{ RTP d/yr}) \times 4.7 \text{ h/d)}] \times 0.116 \text{ (\$/kWh)} \qquad (3)$$

which equals the projected savings of $150,000 per year. The estimated setback hours in *Equation 2* is difficult to model because the actual hours encountered are based on many factors that affect the price of electricity; with outdoor air temperature being one of the factors. Temperature is a major indicator of general electrical demand use and a major factor in determining the hourly price of electricity. Georgia Tech observed that the average duration of an RTP setback event was 6.2 hours with variation above and below. The number of 4.7 h/d in *Equation 2* comes from the fact that some of the 6.2 hours overlaps with night setback after 6 p.m. For days with RTP events, the average afternoon temperature was found to be 28°C (82°F). By analyzing typical mean year (TMY) data (past 10 years) for Atlanta,[3] the number of days with afternoon average temp above 28°C (82°F) in 2006 was found to be 84 days, and corresponds to the number of days per year Georgia Tech could expect RTP pricing to rise above $0.10/ kWh.

The total projected savings for Georgia Tech, according to *Equation 2*, is $150,000/year at 2006 electric prices, equating to a simple payback period of less than one cooling season.

It is understood that the cost savings estimates in this study could be made more accurate with better baseline data (which was unavailable) or with building energy modeling. The *2005 ASHRAE Handbook—Fundamentals*, Chapter 32, "Energy Estimating and Modeling Methods," has a detailed approach to modeling energy use of existing buildings for establishing baselines and calculating retrofit savings. The approach given there may lead to more accurate cost savings estimates if one has a more complete data set over a cooling season. Specifically, the estimated power savings, when the power that would have been used, is not known may be more rigorously found using bin methods and with other approaches as outlined in the Handbook.

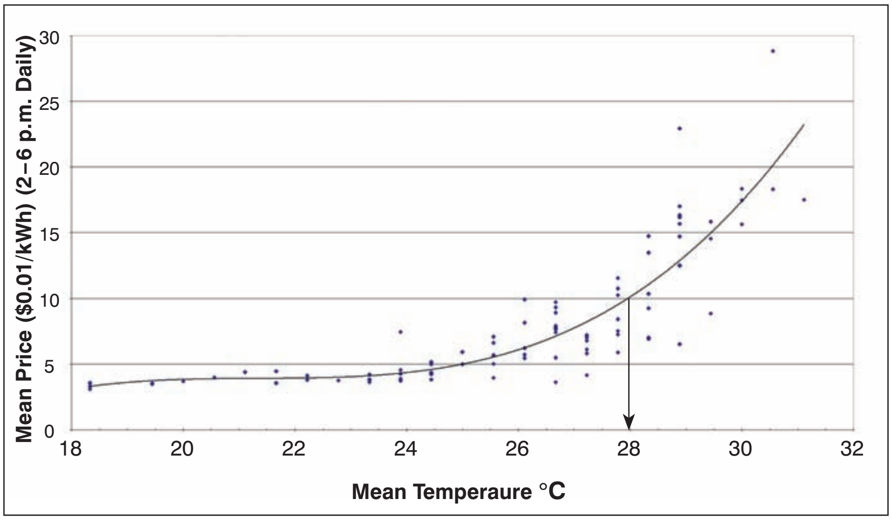

***Figure 4:** Mean cost vs. outdoor mean (2 p.m. to 6 p.m.) temperature (±0.3 °C) for July–September 2006.*

Summary

The Van Leer building at Georgia Tech was selected for a pilot project to study the feasibility of using an RTP-based temperature setback approach to energy savings for the campus. Georgia Tech saved approximately 6,800 kWh of on-peak power and $790 using the RTP conservation strategy in the Van Leer building. The data obtained in the Van Leer building allowed the calculation of a power savings density value that could be applied campuswide and which gave an estimated yearly campuswide cost savings estimate of $150,000. There was less than a one-year payback on the investment necessary to implement the control strategy. This study revealed that more studies need to be performed to determine the ventilation requirements to maintain indoor air quality in spaces when not fully occupied, and apply dynamic adjustments to minimum ventilation setpoints. A benefit, beyond cost avoidance, is that Georgia Tech now has a method based on the dynamics of electrical cost to alter control parameters to allow more saving strategies in the future. Additional strategies are being studied that use the RTP pricing projections to result in additional cost avoidance.

References

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2. Pare, D., S. Bilodeau. 2007. "TES without ice." *ASHRAE Journal* 49(7):46–49.

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