



Leading Techniques for Energy Savings in Colleges and Universities

Learn how building automation products and services can reduce energy costs at colleges and universities.

This paper outlines proven techniques, effective in achieving energy conservation results with an attractive return on investment.

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I. Executive Overview

At colleges and universities, energy consumption has a large impact on both financial and environmental interests. New construction, aging infrastructure, financial constraints, increasing energy costs, and environmental responsibility are motivating institutions to re-evaluate their energy demand and related conservation programs. In a time of growing concern about increasing tuition costs and greater competition for qualified students, institutions must take every measure possible to reduce this large line-item in the budget.

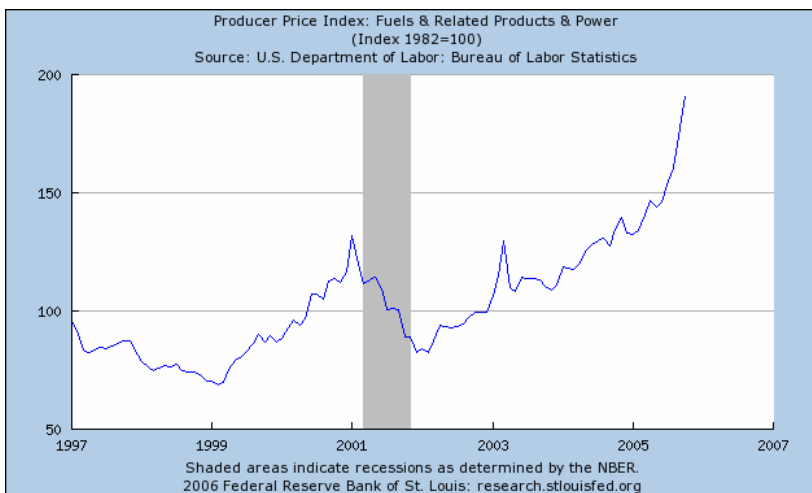
This paper is intended to raise awareness of the many areas of potential savings that relate to energy consumption at colleges and universities. Cost-effective recommendations and best practices will be outlined, demonstrating how management can take action to address energy inefficiencies and implement new initiatives in their energy programs. The reader will also learn some of the often overlooked techniques that comprehensively address energy conservation and increased building operating efficiency.

Finally, this paper will discuss several examples where TAC has effectively applied building automation products and related services to provide optimal facility operations at the lowest possible energy costs.

II. Energy Facts at Colleges and Universities Today

The U.S. Energy Information Administration's (EIA) Annual Energy Outlook for 2006 shows that energy costs rose 31 percent from 2003 to 2005. Using another source to corroborate the EIA figures, *The Producer Price Index for Fuels, Related Products, and Power* clearly illustrates the trend for increasing prices. And high energy prices are forecast to continue due to limited supply and refining capacity, a tense global political climate, and brisk worldwide demand for fossil fuel.

Looking at the academic community, the U.S. Department of Energy (DOE) estimates that at least 25% of the \$6 billion colleges and universities spend annually on energy could be saved through better energy management. Research from the DOE's Building Technologies Program indicates that more efficient lighting



and control, including the use of effective daylighting strategies, can save up to 30% on electrical demand.

It is clear, then, that colleges and universities can do more to reduce energy expenses. And institutions should not only be motivated by budget, but also by the desire to be seen as an energy leader in the community, and environmentally responsible both inside and outside the campus community.

ENERGY CONSERVATION CONTRIBUTES TO BOTH OPERATING INCOME AND HIGHER EDUCATION

Energy efficient campus buildings not only save money, but are also comfortable and have an abundance of natural light. These features contribute to a more effective learning environment. Research has shown that students with the most daylighting in their classrooms performed 20% better in mathematics and 26% better in reading comprehension than those with the least amount of daylighting¹. Moreover, a high quality classroom environment also captures the interest of students and parents alike as they make their college selections from a competitive field.

Research by the EPA shows that facilities that implement energy conservation measures outperform their competitors by as much as 10 percent in net operating income².

The goals achieved through energy conservation also promote awareness of the environment and our limited natural resources; important topics to evangelize in a university setting. The institution then has the potential to become a “laboratory” for students to study engineering and environmental principles³. This fosters a sense of leadership in the student body that helps contribute to lower energy demand and environmental responsibility. Students can monitor energy technologies in use, conduct campus building energy audits, and increase energy visibility in the student community.

ADDING ENERGY MEANING TO THE TERM “COLLEGE TOWN”

Perhaps no other type of business under one management has as diverse a facility infrastructure as that of colleges and universities. To serve populations of students that can reach 30,000 or more, institutions run self-sufficient little towns in-and-of-themselves. A campus has office buildings, restaurants, retail shops, multi-family dwellings, sports facilities, entertainment complexes, and classrooms. Research universities and specialty schools can have museums, medical centers, agricultural centers, high security biomedical laboratories, and many other buildings with very unique characteristics and varied energy needs.

With such diversity of use, operations and maintenance staff responsible for campus facilities must consider not just energy management factors that exist today, but those that may exist in the future as the campus grows. Hence, a building automation system (BAS) needs to have maximum flexibility to adapt to the changing needs of a growing and evolving institution.

Section IV gives examples of specific energy conservation measures and automation methods that can be implemented by the institution’s energy service provider. Techniques that progress from fundamental control to more advanced and integrated applications are outlined for the reader.

¹ Hershong Mahone Group, *Daylighting in Schools: An Investigation into the Relationship Between Daylighting and Human Performance*, 1999

² EPA Study, *Boosting Your Bottom Line through Improved Energy Use*, June 2005

³ Supported by the U.S. Department of Energy, *Rebuild America Program*, www.rebuild.gov

III. Unique Control Considerations of Colleges and Universities

Due to the wide variety of building uses on campuses, energy demand changes from building to building. In residential housing for example, students usually have some degree of manual control and occupant override of HVAC and lighting. In a classroom building, the campus facilities staff will likely schedule the HVAC systems and dictate room temperature setpoints with little or no occupant override capability. Even tighter controls may be specified for laboratories, where strict control of airflow, humidity, and temperature may be required.

So what is special about conserving energy at colleges and universities? And what control applications can be implemented that result in multiple benefits uniquely suited to the campus setting?

HOUSING AND THE CAMPUS CENTRAL LOOP

Where the campus has a central chilled water and/or hot water distribution, new student housing may be connected to the campus central plant for space heating, space cooling, and domestic hot water. This makes campus housing somewhat unique from other multi-family dwellings, which are unlikely to use chilled and hot water for heating and cooling. The interconnection between the campus chilled and hot water loops and the student housing project is a key area where a BAS can help conserve energy⁴.

DAYLIGHTING

When properly designed and effectively integrated with the electric lighting system, daylighting can offer significant energy savings by offsetting a portion of the electric lighting load. Related benefits include a reduction in cooling required, higher student learning retention, and improved comfort. Strategies to get the most of daylighting include light shelves, skylights, clerestory windows, and related controls that optimize daylight using occupancy and photocell sensors.

SUBMETERING CAMPUS BUILDINGS

Decisions about improving energy systems in buildings rest, in part, on detailed knowledge of current energy use. That, in turn, depends upon the metering of all energy sources such as electricity, natural gas, steam, and chilled water. Metering of individual buildings on college campuses is not traditionally practiced, but this is changing as energy costs increase dramatically. Submetering helps allocate costs appropriately by department, encourages conservation, produces more accurate energy reports and profiles, and assists in decision-making about energy upgrades and conservation investments⁵.

ACOUSTICS AND THE CLASSROOM

The impact mechanical system noise has on learning is often considered in design, but seldom given attention after construction is complete. Proper HVAC and lighting maintenance includes control of fan speed, air flow and velocity, and appropriately sized variable air volume (VAV) units. These are important factors to create and sustain the proper learning environment for both students and faculty.

Specific energy saving techniques that relate to these topics are discussed in Section V.

⁴ CTG Energetics, Inc., *Lessons Learned from Commissioning LEED-Certified Campus Housing*, April 2006

⁵ EPA Study, *Sub-Metering Energy Use in Colleges and Universities: Incentives and Challenges*, April 2002

IV. The Role of Building Automation Standards

Most facility managers and staff engineers are familiar with open systems standards such as LON, BACnet[®], XML, TCP/IP, and others that are part of the building automation world. These standards are needed because the product interoperability they represent enables customers to obtain competitive bids from several vendors when construction or renovation projects are in the design phase. After installation and commissioning, these standards then permit flexibility in software programming and alarm notification, often using a single front-end workstation with graphical views of the buildings being managed.

Two aspects of these standards are often confused, but equally important to understand:

BAS integration and **BAS interoperability**. Knowing the difference between the two will help the college or university make the best selection of a new or upgraded BAS, thereby providing the greatest opportunities to effectively implement energy conservation measures today and tomorrow.

BAS INTEGRATION

When controls from multiple vendors communicate through an intermediary gateway or protocol translation device, or have hard wired connections, we call this *BAS integration*. While this is effective in enabling shared data and control between vendors, the wiring, gateway device or translation software does not guarantee future integration when other controls are added to the building or campus. *BAS integration* establishes a static, one-time link between systems that may need to be upgraded when control changes are required.

BAS INTEROPERABILITY

When controls from multiple vendors communicate over a common field-bus network using a common protocol (LON or BACnet), we call this *BAS interoperability*. This not only enables shared data and controls between vendors, but also the assurance that baseline characteristics of the standards are being followed for backward compatibility. Gateway devices and protocol translators are not necessary because the controls themselves comply with the established industry standards. Devices that comply with LON are certified LonMark[®] compatible. Devices that comply with BACnet are certified by the BACnet Testing Laboratory (BTL), and are also known as *native* BACnet.

Choosing to standardize on a single protocol such as LON or BACnet positions the college or university to leverage the best choices of control hardware and software, so future construction projects are designed for the greatest control over energy consumption⁶.



⁶ LonMark is a registered trademark of LonMark International. BACnet is a registered trademark of the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE).

V. Moving Beyond Basic Energy Management

Regardless of the choice between an open or proprietary system, many institutions have some kind of BAS in place for the entire inventory of buildings on campus. It is inexpensive to implement basic controls. However, while initial costs are lowest, the ability to more aggressively manage energy is compromised by these low-cost, fixed-function solutions. This means there is limited or no capacity to do more with the system. Hence, when energy costs rise, there is no easy or cost-effective way to respond because all of the systems' energy saving features are already being applied. Additional costs must then be incurred to implement control strategies that could have been designed from the start in a more scalable BAS.

While the initial costs of basic or proprietary controls may be lowest, the institution's ability to more aggressively manage energy is compromised by these low-cost, fixed-function solutions.

So what kind of control is necessary for optimal energy performance and reasonable return-on-investment? The answer depends on how a given building is currently used, and the desired cost-savings timeframe. In the campus environment, climate control needs can change from building to building, or even room to room depending on the type of facility.

Today's BASs can be expanded to control every piece of equipment in the building, including pumps, fans, valves, dampers, compressors, lighting, and more. Integrated control applications (not to be confused with the protocol discussion of *BAS integration* above) can link disparate functions such as card access to lighting and climate control in any number of divided zones of a building. If a new application of control is necessary, choosing a good BAS results in a flexible and scalable system that protects the institution's initial investment in controls. This makes it possible for the system to be expanded in the future should the need arise. Where existing controls are already in place, management should evaluate whether software can be modified or upgraded to achieve the desired results.

BEST PRACTICE CONTROL STRATEGIES

If a BAS is either being considered or already in place, the options for taking greater control of energy demand increase dramatically. Well designed building automation can save 5% to 20% annually⁷ in energy costs; more if advanced and integrated control techniques are applied throughout the facility.

The following are a few best practice control strategies commonly implemented by BASs and proven financially justifiable by facility managers.

⁷ Portland Energy Conservation, Inc. (PECI) study for the U.S. Department of Energy, *Fifteen O&M Best Practices for Energy-Efficient Buildings*, September 1999.

Fundamental Control Applications

This is the starting point for the facility manager that wants to move beyond programmable thermostats or sensor-activated lighting control. Techniques for fundamental control include:



Best Practices - Fundamental

Zone Scheduling – Permits defined sections of a building to have HVAC and lighting reduced or shut down on a schedule. Zone scheduling means that a whole building does not need to run at a 100% comfort setting if on only a few occupants are in a given area.

Night/Unoccupied Setback – Changes the comfort settings (setpoints) of HVAC so that space temperature decreases in winter and increases in summer, thereby reducing demand for heating and cooling during unoccupied hours. This feature can also be done using a programmable thermostat, but with only a few schedules and no flexibility to more aggressively change setback temperatures.

After-Hours Override – Allows temporary changes to comfort settings after-hours. This eliminates the need to modify schedules, which can sometimes become permanent by accident. This also avoids having the entire building run in occupied mode to meet the needs of a small group.

Occupancy Sensors – Detect motion or infrared signatures in the space, and trigger lights or HVAC accordingly. The BAS also enables scheduled overrides or triggers based on card access to an area of the building.

Holiday Scheduling – A calendar defines HVAC and lighting control for classrooms, theatres, lecture halls or labs for an entire calendar year, saving staff time implementing special schedules and ensuring holiday weekdays do not run in occupied mode.

Advanced Control Applications

In most cases, the same BAS put in place for fundamental controls is also capable of more advanced control applications, often with only software changes. Techniques for advanced control include:



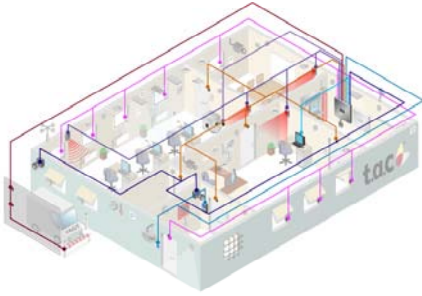
Best Practices - Advanced

Follow Sunrise & Sunset – Permits lighting schedules (such as parking lots, signs, and outdoor access lighting) to vary throughout the year as the length of daylight changes. This prevents lights from being on during the daytime. The BAS automatically computes sunrise and sunset based on the latitude and longitude of the building's location.

Daylight Harvesting⁸ – In zones of the building near exterior walls and windows, lighting can be dimmed or shut off based on specified minimum lighting levels detected by photocells. Controlled use of motorized shades can also optimize the availability of natural light without compromising energy efficiency. See also pages 4 and 5 on how daylighting benefits learning.

Optimum Start – Starts HVAC equipment only as early as required to bring the building setpoints to comfort levels for occupancy. Control routines take into account outside air temperature and inside space temperatures when initiating classroom or lecture hall warm-up or cool-down cycles. Optimum start takes the guess-work out of scheduled startup.

⁸ According to the California Institute for Energy Efficiency and the U.S. Department of Energy, 77,000,000 MWh of electricity are consumed in the United States each year for lighting buildings' perimeter zones where daylight is already present.



Best Practices – Advanced (cont.)

Optimum Stop – Determines the earliest possible time to initiate setback temperatures before unoccupied periods while still maintaining occupant comfort. Also known as “coasting.” Space temperature drifts gradually beyond comfort levels in anticipation of the unoccupied period.

Ventilation On Demand – CO₂ levels in the occupied space are used as an indicator of the number of occupants in a larger room, such as a theatre or lecture hall. Calculations are then performed that relate the CO₂ level to the fresh air intake damper, indicating when more outdoor air is needed. CO₂ levels also assist heating and cooling anticipation in thermostatic control to optimize comfort and air circulation.

Variable Air Volume (VAV) Supply Air Temperature Reset – The supply air temperature (SAT) of variable volume air handlers can be reset upwards when full cooling is not required. The SAT setpoint is increased on cooler days based upon the actual building load. Then when terminal boxes reach 100% open, the SAT is decreased. This minimizes the need for mechanical cooling, optimizes the use of economizers, and improves occupant comfort by reducing drafts due to the movement of excessively cold air.

Demand Limiting or Load Shedding – Monitors electric meters and current draw on high-demand equipment, then relaxes setpoints to immediately reduce demand. This technique can, for example, prevent a chiller from further loading, but can also globally change setpoints throughout the building to shed electric load to avoid peak utility charges. Non-critical equipment and lighting loads can also be shut off.

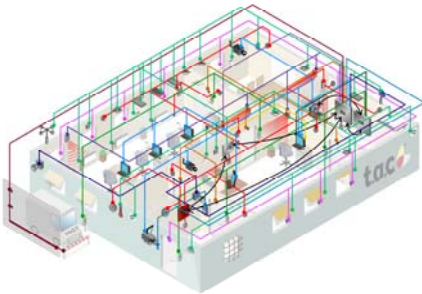
Chiller Optimization – The chilled water loop temperature can be raised as the cooling requirements for the building are reduced, increasing chiller efficiency. A technique known as “load reset” raises the chilled water temperature setpoint until one of the chilled water valves is 100% open.

Cooling Tower Optimization – The condenser water supply to the chiller can be decreased to a minimum setpoint, as defined by the manufacturer. Then an optimal water supply setpoint can be calculated using a combination of the outside air wet-bulb temperature and the cooling tower approach temperature. The reduced water temperature improves the chiller’s partial load efficiency and also optimizes the cooling tower’s operation.

Hot Water Reset – Hot water system temperatures can be reset based on outside air temperature, decreasing heat losses in supply piping. This not only saves energy, but also makes the occupied space more comfortable because it reduces localized heating caused by excessively hot pipes.

Integrated Control Applications

The concept of integrated control is an extension of fundamental and advanced control, but with links to more diverse parts of campus facilities. Integrated control provides a high level of potential business benefits, plus the flexibility to expand control, at least cost, for future energy savings objectives.



Best Practices - Integrated

Variable Frequency Drives (VFDs) – VFDs optimize the power consumed by HVAC fans, speeding up or slowing down the fan based on climate demands of the space under control. Using VFDs, a 20% reduction in fan speed (and air flow) results in a 49% decrease in electrical consumption. Integrated control of VFDs can also be part of a load shedding strategy.

Multiple Use Card Access – Cards used by students or faculty permit access to specific authorized areas. When integrated with the BAS, cards can also be used to trigger lighting and climate control. This is especially useful to save energy in areas that have unpredictable occupancy periods. The same cards can be used for cost accounting at the cafeteria, gymnasium, laundry facilities, or other fee-for-service locations.

Reporting – The BAS produces weekly, monthly, or annual trends in energy consumption. These can include custom reports that verify bill-back or sub-metering charges by department or building. Proper reporting provides early warning when energy efficiency begins to “drift.” Many options for reporting are available using BAS data.

Smart Circuit Breakers – The BAS runs software that can switch on and off electrical circuit breakers (known as “smart breakers”). This enables integrated control of lighting and electrical consumption, which reduces the need for a separate lighting control system installation, training, and maintenance.

Third-party Equipment – Systems such as HVAC equipment, fire detection systems, alarm systems, smoke evacuation systems, and elevators are integrated into a single BAS. This type of integration brings total control of the facility to a single graphical interface.

Central Monitoring and Control – Maintenance staff or the energy manager can monitor and control the whole building from a single console, either on-site or remotely over the Internet. Alarms defined by the user can appear at the console, or be sent to an email address or cell phone.

These are examples of best practices in control operations, though not an exhaustive list. There are many techniques that apply to the specific equipment at colleges and universities in a design-to-suit offer. No matter what level of automation or control is present, the facility director should be inquiring with their supplier about whether any of these techniques can be achieved with modifications to an installed BAS.

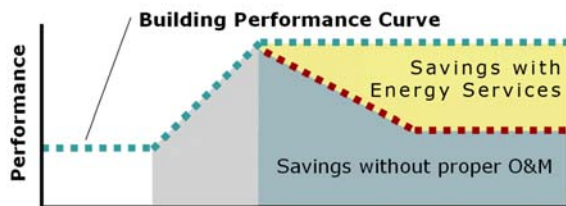
VI. Energy Services

We have discussed the unique facets of energy use at college campuses. And we have outlined best practice techniques that apply a BAS toward solving the costs related to energy demand. This section now discusses energy services, and how ongoing review of energy practices can ensure energy management objectives are continuously being met.

THE COMPLETE BUILDING ENVELOPE

Unless a BAS is maintained and upgraded regularly, it is likely there are energy inefficiencies. Buildings are known to “drift” out of control over time due to reconfiguration, changes in use, staffing changes, and relaxed operations and maintenance (O&M) practices.

Energy conservation measures should not be looked at individually without considering how they interact and impact other planned steps toward energy efficiency. So an important aspect of energy conservation is to manage demand with control systems **combined with** energy services that apply to the complete building envelope, including the windows, walls, foundation, basement slab, ceiling, roof, and insulation. Looking at the



building envelope broadens energy management beyond just smart BAS techniques. It considers non-control facets of the building that can affect energy demand. Energy services, usually part of an energy program, are designed to **maintain** optimum energy efficiency after initial efforts to establish energy conservation are put in place.

TYPES OF ENERGY SERVICES

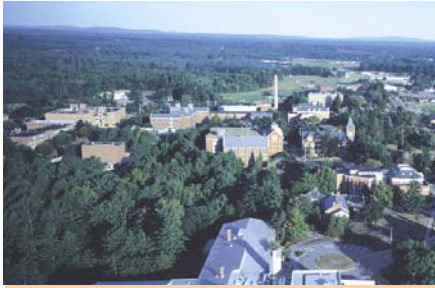
Experience tells us that early identification of excessive energy expenses can often be corrected for very little cost with regular service to controller software, schedules, and economizer operation, and by practicing simple and inexpensive maintenance procedures. Ignoring, or not even seeing spikes in energy costs can consume many times what the remedy would have cost had it been implemented in a timely manner. Energy services that look at the complete building envelope include:

- Outsourced remote monitoring and reporting
- Outsourced operations & maintenance, including controls
- Alarm notification and mechanical service response
- Building automation system fine-tuning
- Periodic energy audits and reports of recommendations

- Evaluations of infrastructure that relate to energy consumption, such as roofing, glass, airlocks, insulation, etc.
- Assistance finding government rebates and financing
- Comprehensive energy efficiency programs, such as TAC EnergyEdge

Once initial steps are taken to maximize energy efficiency, periodic reviews ensure building configuration, equipment, controls, or other systems have not been altered by users or maintenance staff. Energy efficiency “drift” can defeat the best intended energy program. A trained and qualified energy specialist understands the complete building envelope. Expert services, combined with effective knowledge of controls helps colleges and universities maximize savings, not just once, but on an annual basis.

VII. Examples of TAC Customer Solutions



University of New Hampshire

University of New Hampshire (UNH) is a nationally recognized energy leader, receiving awards from the U.S. Department of Energy (DOE) for being in the top 5% of energy-efficient research universities in the country. UNH chose TAC for its flexible software that allows additional control sequences to be implemented as required.

Solution

TAC partner BASiX has installed and serviced more than 1,000 controllers at UNH's 40 buildings since 1981. The TAC system controls the central steam and hot water plant, indoor lighting, and the unique needs of diverse types of buildings on campus. A high-rise building required extra heat in specific zones when windy conditions prevailed. An anemometer that detects wind velocity now helps control building setpoints. In a laboratory, high fume hood air velocity was placing increased demand on heating and cooling. VAV air supply was then set to match that of the fume hoods, minimizing energy consumption while maintaining student safety. The DOE award was also influenced by the skills of UNH's technical staff, which continually monitor the TAC system and make software changes as needed to sustain energy conservation.

Gains

UNH saves more than \$4 million in energy costs each year using a well-designed control strategy, and attention to ongoing efficiency. Energy use at the university is only 181 kBtu per square foot, compared to a regional average of 250 kBtu/sf.



Chippewa Valley Technical College

Chippewa Valley Technical College (CVTC) enrolls 4,000 students on 5 campus locations in Wisconsin. CVTC selected TAC for energy management to maximize their flexibility to control individual classrooms and integrate card access control.

Solution

The TAC system controls heating, ventilation, and air conditioning on all 5 campuses, and uses a central monitoring workstation on the Eau Claire campus. CVTC employs techniques such as optimum start, load shedding, outdoor air damper control, outdoor lighting control, and access control that triggers HVAC zones. One technique that schedules VAV boxes and air handlers individually permits the college to set comfort levels in classrooms based on occupancy and teaching schedules.

Gains

CVTC has the lowest energy use of all the state's 16 technical colleges, yielding a net savings of \$400,000 per year. CVTC was also able to increase comfort levels in classrooms to 72-73 degrees from 70 degrees and still reduce energy expenses. In some buildings, return-on-investment was achieved in 3.5 months.

VIII. Conclusion

An effective building control system is not a commodity, nor is it a cost. A well engineered and maintained building automation system can provide a return on investment over many years. Ensure that the automation system you install or modify is fully programmable to take advantage of the control strategies outlined in this paper.

Make sure the energy conservation measures you put in place today are sustained over time. The best way to do this is to use energy services from a provider that understands the complete building envelope and the interrelated aspects of the building that affect energy demand.

Finally, require your solution provider reduce your building's energy costs immediately, provide a sensible return-on-investment timeframe, and convey confidence that they are proposing products or services that are necessary and effective to achieve your energy savings goals.

TAC is a leading expert in energy services, with customers in 75 countries and more than 500 offices around the world. As a company of Schneider-Electric, TAC brings the resources of a \$14 billion parent company with 92,000 employees to help meet the requirements of any power or control need. To learn more about how TAC can help you achieve your business goals in the college and university market, visit www.tac.com or call 1-866-TAC-INFO.



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