Using Time-of-Day Scheduling To Save Energy

By **John Murphy,** Member ASHRAE; and **Neil Maldeis, P.E.**

Proper scheduling is one of the best opportunities to save energy in existing facilities. This article includes the results of implementing time-of-day scheduling on actual energy retrofit projects, and discusses overlooked opportunities for using this "low tech" idea to save energy. Although some of the control strategies discussed in this article are required by ASHRAE/IESNA Standard 90.1-2007,[1] there are many facilities (existing and new) where they are not used.

Many buildings use some method to automatically shut off HVAC systems based on time of day. Small buildings with simple systems may use a time clock to perform this function. In facilities that have a building automation system (BAS), time-of-day scheduling software is typically a built in function.

Night Setback

The most common use of time-of-day scheduling is to start the HVAC system before the building will be occupied, and to shut it off when unoccupied. When the building is occupied, the BAS controls the HVAC system to maintain the indoor temperature within a desired range for occupant comfort, between 70°F (21°C) and 75°F (24°C) for example. (This desired temperature range may be different in some facilities to satisfy process requirements.)

When the building is unoccupied, the BAS allows the indoor temperature to drift away (cooler or warmer) from the occupied temperature setpoints (*Figure 1*). But

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the system must still prevent the building from getting too cold or too hot. In addition, when unoccupied, the building typically does not require outdoor air for ventilation, so the outdoor-air dampers can be closed.

Allowing the indoor temperature to drift during unoccupied periods, often called night setback, saves energy by avoiding the need to operate heating, cooling, and ventilating equipment. *Figure 2* shows the potential energy savings of using night setback in an example office building equipped with a traditional water-source heat pump system.[2]

If the indoor temperature is allowed to drift when unoccupied, the HVAC system must start prior to occupancy and operate long enough for the indoor temperature to reach the desired occupied setpoint by the time people are expected to enter the building.

Use zone temperature sensors with a BAS instead of programmable thermostats. To lower installed costs, some buildings use simple, residential-style, programmable thermostats with no building automation system. A programmable thermostat can vary the temperature setpoint based on time of day and day of the week, allowing for night setback. But these devices also allow the building occupants to override setpoints or ignore the schedule (by using the hold feature of the thermostat), undermining the potential for energy savings.

A more sustainable approach is to use zone temperature sensors and a building automation system that coordinates the operation of all components of the HVAC system. Operating schedules are adjusted through the BAS, and cannot be overridden by the occupants using the hold feature on a programmable thermostat.

Avoid overly conservative scheduling through the use of timed override buttons. Determining the times to start and stop the HVAC system is typically based on assumptions regarding building occupancy. Most building managers or operators want to avoid complaints from the occupants and the time required to respond to those complaints. For this reason, many take a conservative approach, starting the system early and stopping it late. This practice can be costly from an energy perspective, since the entire building may be operating to maintain occupied temperature setpoints, even though only a few spaces are occupied.

A relatively simple solution to minimize comfort complaints and avoid wasting energy is to equip the zone temperature sensor with a timed override button. If a person wants to use a space during a time when it has been scheduled as unoccupied, they simply press this button and the BAS switches that zone into the occupied mode. This returns the temperature to the occupied setpoint and delivers ventilation air to that zone. Typically, the BAS automatically returns this zone to the unoccupied mode after a defined fixed period of time (two hours, for example).

Using the timed override feature allows the opportunity to be more aggressive with time-of-day operating schedules. This also helps avoid wasting energy by starting and stopping the HVAC system based on typical use, not worst-case or once-a-year use. Once occupants are educated about using the timed override feature, energy savings and minimal complaints can coexist.
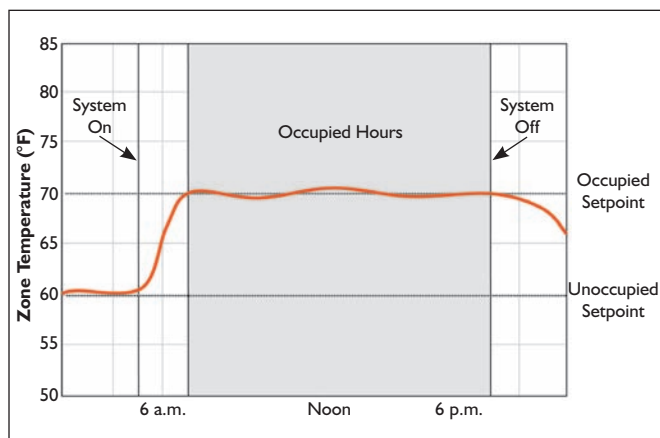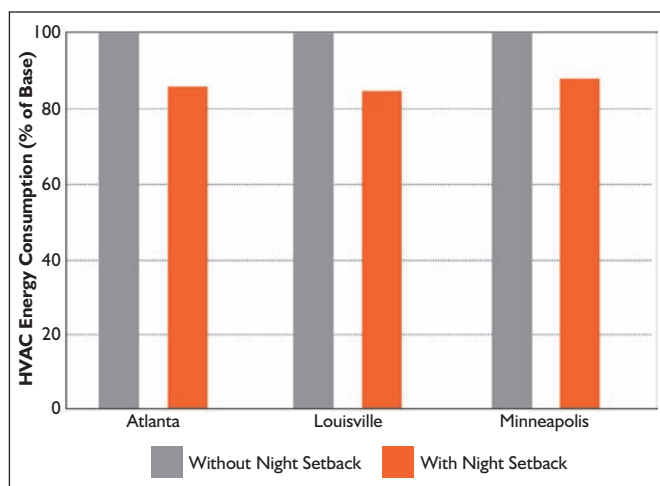

Figure 1: Night setback.

Figure 2: Energy saving potential of night setback.

Use separate time-of-day schedules for areas with differing usage patterns. For simplicity, many building managers or operators define only one (or a few) time-of-day schedules to operate the entire building. However, if areas of the building have significantly different usage patterns, this approach wastes energy because the entire building may be operating to maintain occupied temperature setpoints, although only part of the building is in use.

A more energy-efficient approach is to create separate time-of-day operating schedules for areas of the building with significantly different usage patterns. If the facility has a building automation system, it probably includes a time-of-day scheduling function, the only additional cost is the operator's time to set up the schedules.

Results from Actual Energy Retrofit Projects

Time-of-day operating schedules are often a significant opportunity to save energy in existing buildings. The following are the results of two energy retrofit projects.

The first example is a small school district located in Michigan. This project included implementing time-of-day scheduling and night setback in three school buildings, total-

ing 380,000 ft^2 (35 300 m^2). Before the project commenced, the annual utility cost for these three buildings was just under $300,000. *Figure 3* shows the actual measured energy savings during the four years following implementation. In the first year, proper time-of-day scheduling and night setback reduced energy use and saved $70,000 in utility costs. Although the amount of energy saved was sustained over the next three years, a rate increase for natural gas at the beginning of the second year grew the utility cost savings to nearly $150,000.

The second example is a 97,000 ft^2 (9000 m^2) government office building located in Florida. This project also included implementing time-of-day scheduling and night setback. Before the project commenced, the annual utility cost for the building was $108,000. *Figure 4* shows the measured energy savings during the two years following implementation. In the first year, proper time-of-day scheduling and night setback reduced energy use and saved almost $15,000 in utility costs. Similar to the first example, a utility rate increase at the beginning of the second year grew the savings to $20,000.

In energy retrofit projects, we have historically found more potential for energy savings through proper scheduling and night setback than from any other energy-saving strategy. *Figure 5* demonstrates this by comparing the estimated versus measured energy savings from several energy-saving strategies that were implemented for a school district in Virginia (six buildings, totaling 475,000 ft^2 [44 100 m^2]). Notice that the energy saved through building automation accounted for nearly half of all the energy saved by the project.

Based on this author's experience, the savings from properly controlling an existing building is between 10% and 15% of the annual utility costs. Time-of-day scheduling and night setback are part of this.

Overlooked Opportunities

Although the use of time-of-day scheduling for night setback is well understood, there are other often overlooked opportunities to use this low tech idea to save energy in buildings.
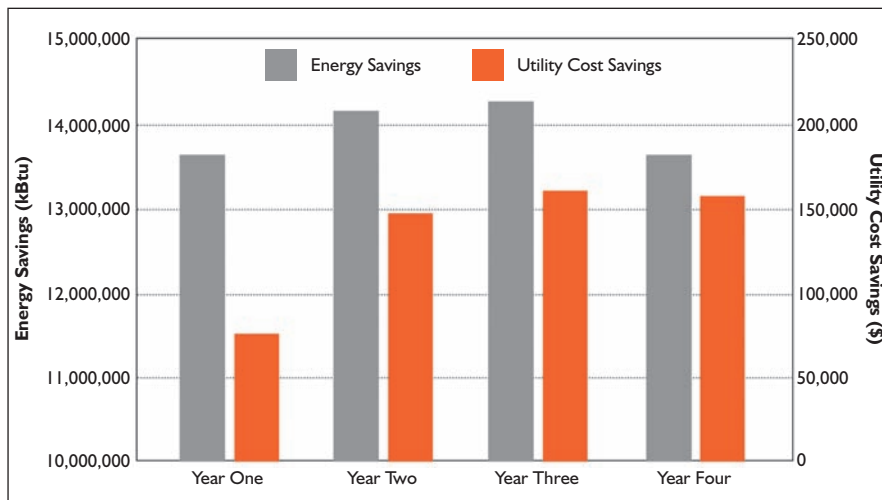

Figure 3: Measured energy savings for a small school district through proper scheduling and night setback.
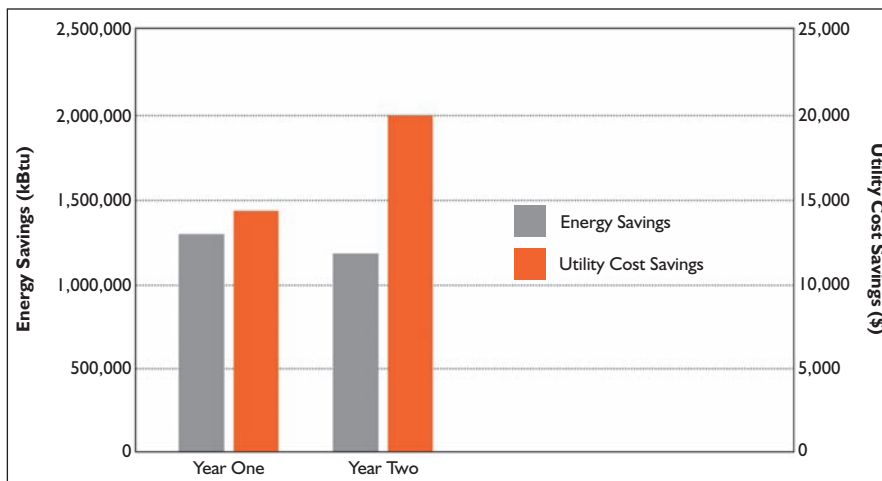

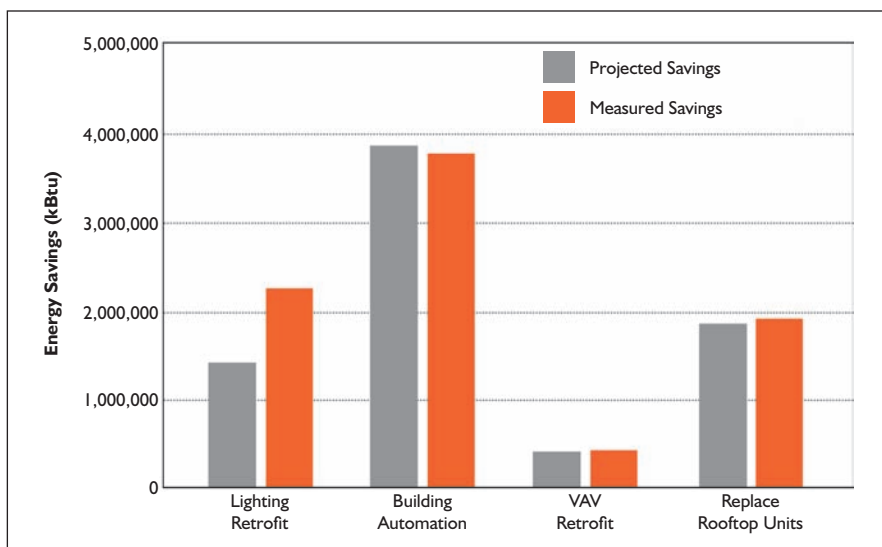Figure 4: Measured energy savings for a government office through proper scheduling and night setback.

Figure 5: Comparison of energy saving measures for a school district.

Use for demand-controlled ventilation in certain space types. Demand-controlled ventilation (DCV) is a strategy that attempts to dynamically reset the outdoor airflow delivered to a zone based on changing population within that zone. Commonly used technologies include CO_2 sensors and occupancy sensors (motion detectors), but time-of-day schedules are an often overlooked option.

A time-of-day schedule can be created in the BAS to predict the number of people that occupy a zone throughout the day. This variation in population can then be used to reset the required ventilation airflow for the zone. This approach is best suited for spaces where the occupancy pattern is predictable, such as cafeterias, gymnasiums, and some classrooms.

If the facility contains a BAS, it probably includes a time-of-day scheduling function, the only additional cost is programming time to set up the schedules. And, unlike a CO_2 sensor, this technology does not need to be periodically cleaned and calibrated, so it is more reliable. However, there are spaces where CO_2 sensors are worth the added cost and risk. But, for any space with a predictable occupancy pattern, a time-of-day schedule can reliably deliver significant energy savings without additional sensor cost.[3]

Combine with occupancy sensors to enable an occupied standby mode. When an occupancy sensor is used in combination with a time-of-day schedule, the sensor can be used to indicate if the zone is unoccupied although the BAS has scheduled it as occupied. This combination is used to switch the zone to an "occupied standby" mode. In this mode, all or some of the lights in that zone can be shut off, the temperature setpoints can be raised or lowered by 1°F to 2°F (0.5°C to 1°C), and the ventilation delivered to that zone can be reduced, typically to the building-related ventilation rate, Ra, required by ANSI/ASHRAE Standard 62.1.[4]

In addition, for a multizone variable-air-volume (VAV) system, the minimum primary airflow setting of the VAV terminal serving that zone can be lowered to avoid or reduce the need for reheat. These minimum primary airflow settings are typically selected to ensure proper ventilation or to increase air circulation for occupant comfort. However, with no occupants and a reduced ventilation requirement, the minimum primary airflow setting can be lowered significantly.

When the occupancy sensor indicates that the zone is occupied, the zone is switched back to occupied mode.

Optimize HVAC system operation. When a building automation system is used for time-of-day scheduling, the next logical step is to use it to optimize the control of the system and reduce energy use.[5]

Optimal start. When night setback is used, the HVAC system must start prior to occupancy and operate long enough for the indoor temperature to reach the desired occupied setpoint by the time people occupy the building. In many buildings, the time-of-day schedule is programmed to start the system early enough so that the building will warm up or cool down fast enough on the worst-case morning. As a result, for all other days of the year, the system starts earlier than needed. This increases the number of operating hours and increases energy use.

An alternative approach is a strategy called optimal start. The BAS is used to determine the length of time required to bring each zone from its current temperature to the occupied setpoint temperature. Then, the controller waits as long as possible before starting the system, so that the temperature in each zone reaches the occupied setpoint just in time for occupancy.

The optimal starting time is determined using the difference between the actual zone temperature and the occupied setpoint temperature. It compares this difference with the historical performance of how quickly the zone has been able to warm up or cool down. Some systems also compensate for the current outdoor temperature.

This strategy reduces the number of system operating hours and saves energy by avoiding the need to maintain the indoor temperature at occupied setpoint prior to the beginning of the scheduled occupied period.

Optimal stop. A related strategy is optimal stop. As mentioned previously, at the end of the scheduled occupied period, the HVAC system is shut off and the indoor temperature is allowed to drift away from the occupied setpoint. However, the building occupants may not mind if the indoor temperature drifts just a few degrees before they leave at the end of the day.

Optimal stop uses the BAS to determine how early heating and cooling can be shut off for each zone, so that the indoor temperature drifts only a few degrees from the occupied setpoint. Only cooling and heating are shut off; the supply fan continues to operate and the outdoor-air damper remains open to continue ventilating the building. Consider disabling optimal stop during humid weather to avoid introducing unconditioned outdoor air into the building.

The optimal stop strategy also reduces the number of system operating hours, saving energy by allowing indoor temperatures to drift prior to the end of the scheduled occupied period.

Unoccupied economizing. During the unoccupied mode, the indoor temperature can sometimes drift warmer than the occupied cooling setpoint temperature. This requires the HVAC system to start and cool down the building prior to scheduled occupancy. However, if the outdoor dry-bulb temperature is cooler than the indoor temperature during some part of the unoccupied period, it is possible to use the outdoor air for "free" cooling. This strategy, often called unoccupied (or nighttime) economizing, can save energy by precooling the building prior to the morning cool-down period.

Unoccupied economizing uses the BAS to determine if the condition of the outdoor air is suitable for free cooling, and determines which zones could benefit from precooling. For example, unoccupied economizing may be allowed whenever the outdoor dry-bulb temperature is cooler than the zone temperature by a defined margin, 15°F (8°C) for example. Then, the BAS starts the fan and opens the outdoor-air damper, precooling the building to a preset temperature before turning the system off. In addition, a humidity sensor can be added to prevent unoccupied economizing when the outdoor air is cool, but humid.

Integrate with other subsystems to optimize HVAC energy use. When a facility has other control systems installed, there may be opportunities to integrate with them to further reduce HVAC energy use. As discussed previously, the same time-of-

day scheduling function that operates the HVAC system can also be used to turn on and off lights inside the buildings.

In a building that uses a card access security system, data from that system could be used to turn lights on and off or adjust the amount of ventilation airflow delivered to a specific area of the building.

In a theater complex, information from the ticket sales system could be used to adjust the amount of ventilation airflow delivered to a specific theater, based on known ticket sales for that show.

Sustaining Performance

Just as regularly scheduled maintenance helps equipment operate as intended, regular checkups (or periodic commissioning) help to maintain the energy savings expected through proper time-of-day scheduling.

As mentioned previously, most building managers or operators want to avoid complaints from the occupants and the time needed to respond to those complaints. In response to a complaint, it is often easier and quicker to override a schedule or setpoint and attempt to determine the actual cause later. During the busy schedule of a building operator, however, these temporary changes or overrides often become permanent, wasting energy.

Figures 6 and 7 show example charts generated from trend data provided by a building automation system. This type of data helps the operator or remote service provider identify changes or overrides to the time-of-day schedules or temperature setpoints for various areas in the building. Some of these changes may need to remain permanent, but many can be returned to their intended state, restoring energy-efficient operation.

Summary

Time-of-day scheduling for night setback is well understood. However, the programming of a building automation system is typically changed after initial installation, often taking a conservative approach to minimize occupant complaints. This can be costly from an energy perspective.

Avoid overly conservative scheduling by using timed override buttons, use separate time-of-day schedules for areas with differing usage patterns, and use zone temperature sensors with a BAS rather than programmable thermostats. These simple strategies help improve this low tech idea to save energy without sacrificing occupant comfort.

In addition, there are other overlooked opportunities for using time-of-day scheduling to save energy in buildings.
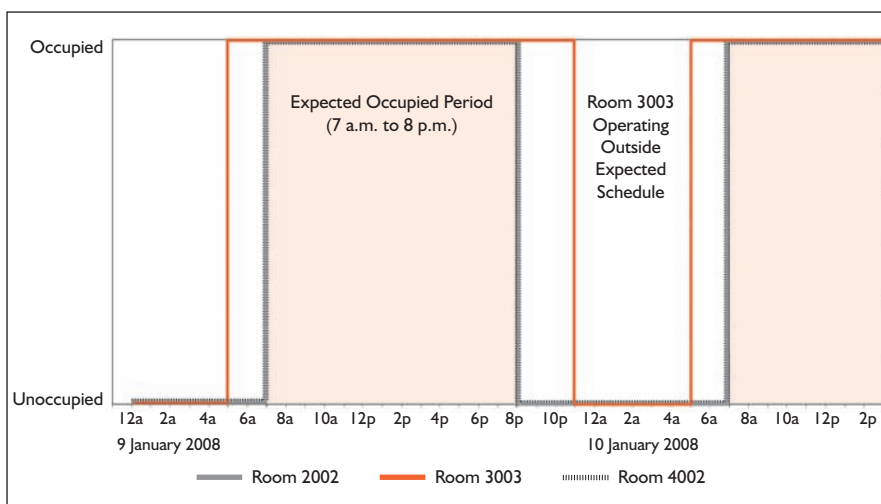

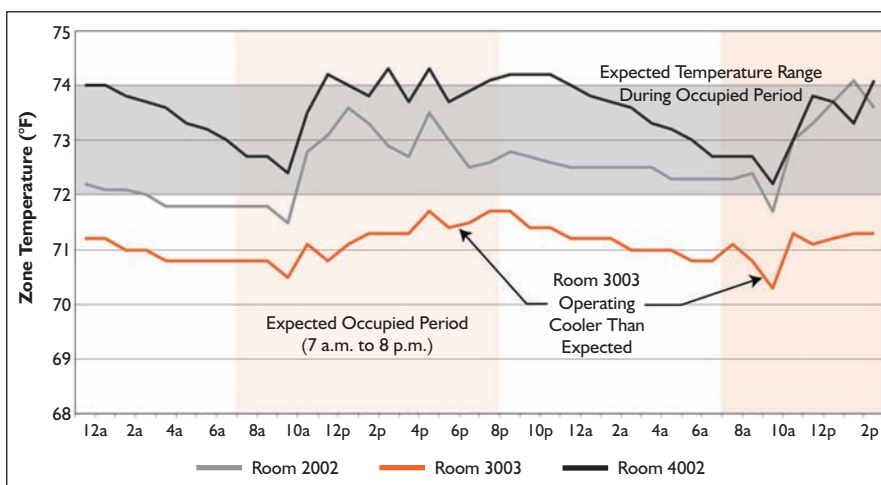Figure 6: Sample trend data of time-of-day schedules.

Figure 7: Sample trend data of zone temperatures.

Zones with predictable occupancy patterns are good candidates for using time-of-day scheduling for DCV. Combine an occupancy sensor with a time-of-day schedule to enable an occupied standby mode for saving energy throughout the day. With the BAS in place, use it to optimize the operating schedules of the HVAC systems to reduce energy use, and monitor system operation to sustain energy-efficient performance.

References

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2. Murphy, J. 2007. "Energy-saving control strategies for water-source heat pump systems." *Engineers Newsletter* 36-2. La Crosse, Wis.: Trane.

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5. Murphy, J. 2007. *Rooftop VAV Systems* applications engineering manual SYS-APM007-EN. La Crosse, Wis.: Trane.●