Heating, Ventilation and Air Conditioning Controls

Controlling HVAC for efficiency and comfort

Space heating, cooling and ventilation account for nearly half of the energy consumed by small commercial buildings (Figure 1). Ensuring your equipment is operating as efficiently as possible is critical to reducing your building's energy consumption and cutting operational costs while maintaining occupant comfort.

Controls are arguably the most important part of a heating, ventilation and air conditioning (HVAC) system since the control system translates human needs for heating, cooling and ventilation into a language heat-and-air-moving machines are capable of understanding and addressing. Appropriate thermostat programming can dramatically reduce unnecessary HVAC equipment operation, saving energy and extending equipment life.

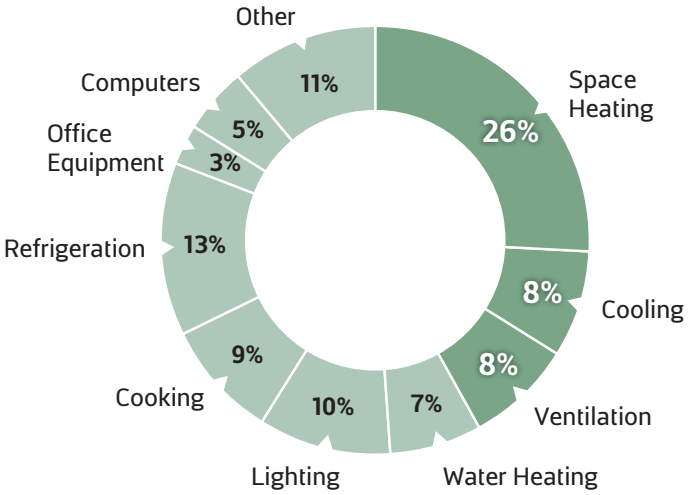
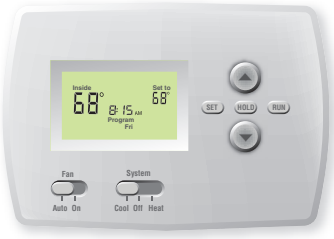


Figure 1 – Energy Consumption End Use, Commercial Buildings <50k s.f.[1]



THERMOSTAT BASICS

A building's HVAC equipment is controlled from the thermostat which, in its most basic form, can be set to maintain a desired temperature within a zone served by a heating or cooling system. A programmable thermostat is a more advanced unit that can be used to schedule multiple temperature set-points throughout the week.

SCHEDULES

Programmable thermostats come in three different scheduling configurations:

- **5-2:** One schedule set is used for Monday through Friday and a second schedule set is used for Saturday through Sunday.
- **5-1-1:** One schedule set is used for Monday through Friday, a second schedule set is used for Saturday and a third schedule set is used for Sunday.
- **7-day:** There are seven different schedule sets, one for each day of the week.

Programmable thermostats typically have four scheduling periods per day: Wake, Leave, Return and Sleep. Commercial buildings typically only need two scheduling periods per day. Wake and Return are occupied scheduling periods. Leave and Sleep are unoccupied schedule periods.

Setting a thermostat to "Hold" tells the thermostat to ignore all programming and simply maintain the current temperature. Thermostats that are only set to "Hold" are a very common issue that result in wasted heating and cooling energy.

SYSTEM MODE

If the thermostat is in heating mode and the temperature is colder than the set-point, then the thermostat calls for heating by activating the supply fan in the air handling unit (AHU), while providing a source of heat that is transferred to the supply air through heating coils. If the thermostat is in cooling mode and the temperature is warmer than the set-point, then the thermostat calls for cooling by activating the supply fan (in the AHU), while providing a source of cooling (i.e. heat removal) that is transferred to the supply air through cooling coils. When the temperature set-point is satisfied, the thermostat tells the supply fan and the heating/cooling equipment to stop operating.

At the Greenwood Boys and Girls Club, occupancy sensors were connected to a demand control ventilation system. Initially costing $26,350, this implementation saved the facility $6,500 per year.

When the system mode is set to "Off," the heating/cooling equipment and supply fan will not operate, regardless of interior temperature or set-point. Heat pump thermostats typically have an emergency heat mode. When operating in emergency heat mode, the system operates the auxiliary heating system–typically electric resistance–instead of heating with the primary heating system (heat pump). Emergency heating mode should not be used unless the refrigeration system is damaged, in temperatures lower than 40 degrees or the heat pump is rendered inoperable for other reasons.

Some thermostats can automatically switch between heating and cooling mode without user intervention.

FAN MODE

The supply fan can typically be set to one of two modes: "Auto" or "On." When the fan is set to automatic ("Auto") mode, the supply fan operates only when there is a call for heating or a call for cooling. When the fan is set to on ("On") mode, the supply fan operates continuously. Some thermostats have a third fan mode: "Circ." When the fan is set to circulate ("Circ") mode, the supply fan operates continuously during occupied periods and turns off during unoccupied periods, unless there is a call for heating/cooling.

Systems that supply ventilation air via a passive outside air intake using the supply fan should generally be operated with the fan set to "Circ" in order to deliver ventilation air continuously when the building is occupied. Setting the fan mode to "Auto" will minimize energy consumption, but ventilation air will only be introduced when the system is heating or cooling. Setting the fan mode to "On" will result in much higher energy use, since the supply fan never turns off. In addition, systems that deliver outside air from a passive outside air intake will introduce outside air continuously, which will further increase energy used for heating/cooling and may cause moisture issues in humid climate zones.

BUILDING AUTOMATION SYSTEMS

Total building automation systems (BAS) are becoming more common place and beneficial in smaller commercial buildings. Very much the "brain behind the walls," BAS controls multiple systems simultaneously within your space: lighting, heating/cooling, alarm systems, ventilation, etc. By controlling all of these systems in a central location, buildings performs better by optimizing equipment schedules and reducing excess usage due to occupant behavior and errors.

COMMON PITFALLS

The most common barrier to effective HVAC controls implementation is the lack of staff and local contractor expertise for operation and maintenance of complicated HVAC control systems. Maintaining optimal thermostat set-points and equipment run-time schedules is a complicated process that requires the close attention of an experienced building operator. Building owners often rely on mechanical contractors to provide guidance on HVAC operations. However, due to miscommunication of occupancy schedules, these arrangements can lead to improperly programmed thermostats increasing energy waste. The following misconceptions about proper thermostat programming and HVAC maintenance can lead to needless energy consumption:

- **Misconception 1** – It takes more energy to warm up or cool down a building following unoccupied periods than it does to keep the temperature constant.

  The opposite is true—aggressive setbacks and setups have been proven to conserve more energy than leaving your system running. Adaptive recovery technology is available for heat pumps to allow a longer ramp-up time and prevent the use of strip heat when getting the building warm during cold mornings.

- **Misconception 2** – If a system is working fine, leave it alone.

  Proper commissioning and preventative maintenance is critical for maximizing energy efficiency. Fixing or replacing equipment upon failure typically leads to hurried replacements and clumsy oversights. Planning for capital improvements will ensure high efficiency equipment is installed and effectively integrated into ongoing building operational procedures.

- **Misconception 3** – Leaving the blower fan running will cool your building.

  While moving air does creates a cooling sensation, it does not actually lower ambient temperature. Leaving your fan running while the building is unoccupied only wastes electricity circulating hot air and adds to any energy losses from duct leakage in unconditioned spaces.

HVAC Controls act as the nerve center of your HVAC system, coordinating the actions of various components to optimize occupant comfort and energy efficiency. Installing a customized controls system will offer the following benefits:

- **Reduces operating costs and increases equipment lifespan** by reducing unnecessary equipment operation, optimizing operating parameters and modulating equipment cycling to prevent excessive wear.
- **Maximizes occupant thermal comfort** through more precise temperature and ventilation control, improving employee health and productivity.
- **Allows remote access to HVAC settings** to address control-related emergency situations from anywhere.
- **Records and displays real-time data** that can be used to identify impending equipment failures, diagnose mechanical problems and address comfort issues.

PROGRAMMABLE THERMOSTAT BEST PRACTICE

The following measures will help to optimize savings from your HVAC control system using a programmable thermostat:

- Install occupancy-based programmable thermostats in intermittently occupied spaces such as cafeterias, gyms and auditoriums.
- Set your thermostats to 70 degrees during the heating season and 75 degrees in the cooling season to minimize energy wasted. (Energy costs go up or down two-three percent for every temperature degree.)[2]
- Install night, vacation and holiday setback programming to avoid running systems 24 hours a day. During unoccupied periods, program thermostats to automatically set back to minimize equipment operating hours.
- Even with a sophisticated HVAC controls system, the human element is still the most important driver of energy efficiency. Train staff about how the new thermostat system works and how programming setbacks can save energy. Teach users how to perform a set-point override without disturbing the programming or using "HOLD."
- Implement an adaptive recovery control sequence that learns how long the HVAC system takes to achieve the desired set point and automatically starts every morning prior to occupancy to allow time for the building to reach temperature after idling all night.[3]

Additional Resources

PNNL Building Re-tuning Interactive Web-Based Training:
www.buildingretuning.pnnl.gov/interactive.stm

COMMON THERMOSTAT TECHNOLOGIES

Thermostats serve as the access point for a user to manipulate the control system. The three most common types of thermostats are listed in the following chart:

	Manual Thermostat	Programmable Thermostat	Wi-Fi Programmable Thermostat
	→ *Increasing thermostat capability and cost* →		
Technology Description	▶ Set-point control at each thermostat. ▶ Heating or cooling set-points. ▶ Fan mode (on/off). ▶ No set-point scheduling.	▶ Set-point control at each thermostat. ▶ Scheduled heating and cooling set-points based on day/time. ▶ Schedule fan mode (on/off) based on day/time.	▶ Set-point control for all thermostats at a central device (computer, smartphone, web user interface). ▶ Schedule heating and cooling set-points based on day/time. ▶ Schedule fan mode (on/off) based on day/time. ▶ Record and trend HVAC and set-point data.
Suitable Applications	▶ Building continuously occupied – 24/7, 365 days a year. ▶ No need to schedule set-point changes based on building use.	▶ Buildings with variable occupancy and on-site personnel responsible for programming set-point schedules for each thermostat.	▶ Buildings with variable occupancies and many thermostats. ▶ Building where group thermostat programming is desired. ▶ Buildings where remote thermostat set-point access is desired. ▶ Buildings where historical trend data of HVAC systems and set-points is desired.
User Notes	▶ Keep thermostat in lock box to prevent occupants from overriding the designated set-point. ▶ Check thermostat regularly to make sure thermostat is set to desired set-point.	▶ Keep thermostat in lock box to prevent occupants from overriding the designated set-point. ▶ Talk to the building owner and occupants, schedule thermostat set-point based on zonal occupied and unoccupied periods. Example recommended set-points: » Unoccupied heating = 55°F » Occupied heating = 70°F » Unoccupied cooling = 85°F » Occupied Cooling = 75°F ▶ Unoccupied periods include nights, holidays, vacations, etc. ▶ Program thermostats to start heating or cooling before the building is occupied in order to reach the desired set-point when the building becomes occupied.	▶ Talk to the building owner and occupants, schedule thermostat set-point based on occupied and unoccupied periods. Example recommended set-points: » Unoccupied heating = 55°F » Occupied heating = 70°F » Unoccupied cooling = 85°F » Occupied Cooling = 75°F ▶ Group thermostats by occupancy schedule to expedite programming time ▶ View trend data online, and adjust set-points to maximize efficiency and proactively avoid maintenance issues and equipment failure. ▶ Remotely access HVAC control settings and address emergency issues anytime
Add-on capabilities and additional considerations	▶ Humidistats may be considered to monitor and control the relative humidity of the conditioned space. ▶ Space use changes will necessitate an on-site manual adjustment of the thermostat.	▶ Optimal start: logic included in thermostat that will automatically initiate mechanical systems at a specific time so set-points are met when building becomes occupied ▶ Adaptive Intelligent Recovery- thermostat “learns” how to optimize HVAC equipment operation. Especially important when heating with heat pumps. ▶ Humidistats may be considered to monitor and control the relative humidity of the conditioned space.	▶ Sensor monitoring » Circuits » Temperature » Humidity » Occupancy ▶ Humidistats may be considered to monitor and control the relative humidity of the conditioned space. ▶ Additional wiring between the air handler and thermostat may be needed.

REFERENCES AND RESOURCES:

1. U.S. Energy Information Administration. (2012). Table E1. Major Consumption (Btu) by End Use.
2. Connecticut School Indoor Environment Resource Team. (2009). Maintaining Good IAQ While Conserving Energy.
3. Pacific Northwest National Laboratory, et al. (2011). Advanced Energy and Retrofit Guides. Office Buildings. U.S. Department of Energy.