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Introduction

In an effort to cost-effectively reduce building-wide overheating, some multifamily building owners choose to install an energy management system (EMS) to control the boiler. The primary function of an EMS in multifamily buildings is to monitor indoor temperatures using a network of temperature sensors and then to use that information to control the heating system. This tech tip focuses on how to use an EMS to better control the run time of the boiler or the temperature of the water circulated through the building.

Background

Many multifamily buildings across New York State are overheated in the winter. In general, the most severe overheating is found in buildings heated by steam and hot water. Frequent causes of overheating are:

- degraded heating distribution systems
- inadequate or improperly calibrated heating system controls
- the complicated reality of heating multifamily buildings

Both New York State Code and New York City Code require a minimum indoor temperature of 68°F during the winter for multifamily buildings. For the purpose of this discussion, we define “overheated” as anything above code minimum, but many building owners aim for a minimum of 70°F to ensure tenant comfort. A range of temperatures is expected, but temperatures more than 72°F are widely considered overheated.

There are many boiler control strategies used to maintain this minimum temperature, and they vary widely in their ability to do so while conserving energy and keeping fuel costs low. Many centralized boiler controls operate without any feedback from indoor temperature sensors, which limits their ability to achieve all three goals. Controls that allow the tenants to adjust the amount of heat coming from a radiator, such as thermostatic radiator valves (TRVs) or thermostats, can reduce both overheating and tenant complaints, but they can be expensive to install. They also typically rely on tenant cooperation to achieve savings. This can make them unappealing for energy conservation retrofits because savings may be unreliable.

NYS and NYC Code Requirements

New York State *– Heat supply. Every owner and operator of any building who rents, leases or lets one or more dwelling unit, rooming unit, dormitory or guestroom on terms, either expressed or implied, to furnish heat to the occupants thereof shall supply heat during the period from September 15th to May 31st to maintain a temperature of not less than 68°F (20°C) in all habitable rooms, bathrooms and toilet rooms. (Section 602.3)*

New York City *– Heat must be supplied from October 1 through May 31 to tenants in multiple dwellings. If the outdoor temperature falls below 55°F between the hours of six a.m. and ten p.m., each apartment must be heated to a temperature of at least 68°F. If the outdoor temperature falls below 40°F between the hours of ten p.m. and six a.m., each apartment must be heated to a temperature of at least 55°F. (Multiple Dwelling Law § 79; Multiple Residence Law § 173; NYC Admin. Code § 27-2029.)*

Figure 1: Central computers of Energy Management Systems installed in the field and manufactured (from left to right) by Heat-Timer, U.S. Energy, EnTech, and Intech 21. Photo credits: Far left and left by Taitem Engineering; right and far right by the Association for Energy Affordability.

Description of Energy Management Systems

Energy management systems have two main functions that differentiate them from other types of boiler controls:

First, many EMSs can **monitor a wide array of data** types and display the data in a computer program or on a website. Depending on the model, data points that can be monitored include domestic hot water temperature, fuel consumption, fuel oil tank level, boiler stack temperature, boiler water usage, and more. Although these monitoring capabilities are often emphasized in marketing materials and can be a useful tool for some boiler operators, they do not produce any energy savings by themselves. Action by the boiler operator is required to turn any of the information listed above into potential energy savings.

Second, EMSs use **a network of temperature sensors** to better control the run time of the boiler or the temperature of the water circulated through the building. One temperature sensor monitors outdoor air temperature. It determines whether the building should be heated at any given time, where on the outdoor reset curve the boiler should operate, or which curve should be used. Additionally a series of sensors is installed in a sample of apartments to monitor the temperature inside the building.

Multiple temperature sensors are recommended to get an accurate picture of what is going on in the building. Measuring temperatures in several apartments reduces the impact of anomalies caused by open windows, electric heaters, and tenants who shut off their radiators. **Best practice:** Install sensors in a representative sample of no fewer than 10% of the apartments; this provides adequate redundancy while keeping costs reasonable. **Best practice:** Install the sensors in apartments on different floors and lines to take into account differences in temperature between upper and lower floors, sunny and shaded sides, and windward and leeward sides of the building. Many EMS manufacturers offer wireless sensors which can reduce installation costs.

The indoor sensors are used to calculate an approximate average building temperature, which the EMS uses to control the boiler. **In steam systems,** this average temperature is used to prevent unnecessary firing when the building's target temperature is already met. That is, the apartment sensors "vote." If enough sensors indicate apartments are warm enough, the EMS keeps the boiler off, and if enough indicate apartments are too cool, the EMS allows the boiler to fire.

In hot water systems, instead of turning the boiler on and off, the EMS uses the apartment temperature data to adjust the outdoor reset curve. For example, if the outdoor reset curve calls for a supply water temperature of 160°F , but the average indoor temperature is close to the setpoint, the outdoor reset curve might be adjusted to provide supply water at 150°F.

Most EMSs can be programmed to lower the indoor temperature at night, which can result in additional savings. We recommend implementing night setback, if permitted by code.

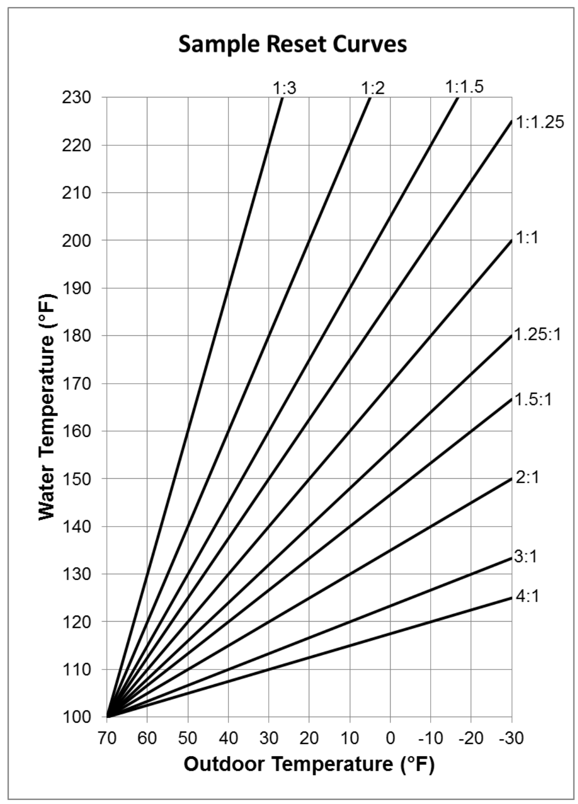
For both steam and hot water systems, the primary result of implementing an EMS is to reduce the average indoor temperature. Keep in mind that the EMS alone cannot supply more heat to specific cold apartments nor reduce the heat supplied to specific hot apartments.

Outdoor Reset Control

*In buildings heated with **hot water,** the use of outdoor reset curves can reduce overheating and save energy by varying the temperature of the water circulating through the building. In general, as the outdoor temperature decreases, warmer water is circulated. Actual water temperatures required are building-specific.*

***Example:** A building might require 140°F circulating water when it is 55°F outside, but 180°F water when it is 20°F outside.*

The outdoor reset ratio defines how much the water temperature is increased per degree of outdoor temperature decrease. For example, with a 1:1 ratio, the water temperature is increased 1°F when the outdoor temperature falls 1°F. With a 1:1.25 ratio, the water temperature is increased 1.25°F for every 1°F the outdoor temperature falls.



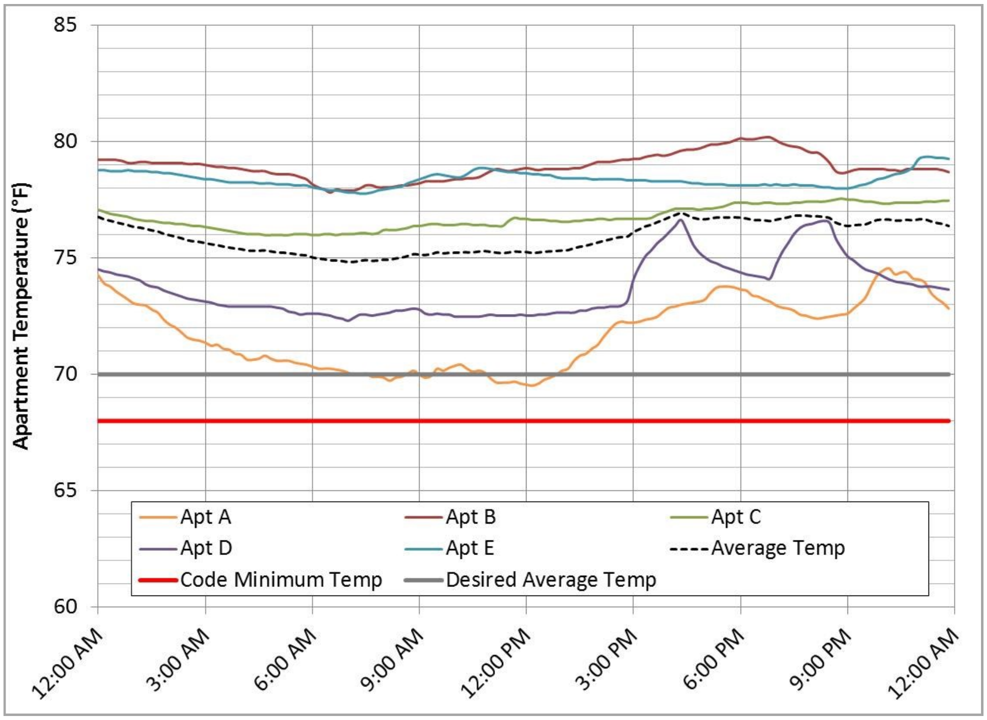


Figure 2: Sample apartment temperatures in a building with no EMS.

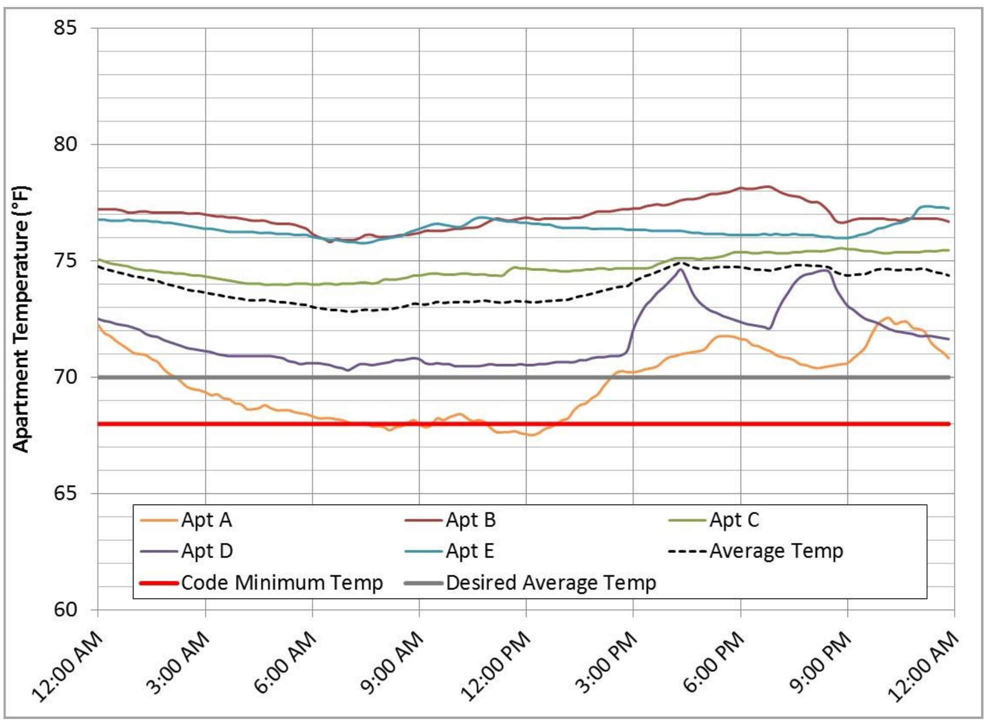


Figure 3: Temperatures in the sample apartments, altered to show the effect of installing an EMS on the boiler.

Main Drawback of EMS

Figure 2 shows the temperature in five apartments for a typical 24-hour period in a building without an EMS. Note that at a few points during the day there is a difference of almost 10°F between the hottest and coldest apartments.

Figure 3 shows the temperatures for the same five apartments, altered to show what the temperature profile might look like in the same building on the same day if an EMS was controlling the boiler. Note that all of the apartment temperatures have decreased by approximately 2°F and the average building temperature has also decreased. The difference between the hottest and coldest apartment is still nearly 10°F at some points. Also, the coolest apartment occasionally dips below the code-minimum 68°F. If the EMS were to decrease the indoor temperature further, the temperature in Apartment A would no longer meet code.

Figures 2 and 3 illustrate the **main drawback** of EMSs: Because they are not able to direct more or less heat to specific apartments, some apartments will continue to be overheated and some savings will be unrealized. Balancing the distribution system so that the apartments are heated more evenly is therefore critical to maximizing savings. Most heating systems were designed to supply heat to all apartments at approximately the same time. Over the years, however, systems may be altered and key components may degrade or fail. The result is that heat may now reach some apartments more slowly than others. These heating imbalances can have many causes, including failed or clogged air vents, failed steam traps, sediment build-up in distribution pipes, removed radiation, removal of vacuum pumps, and others.

Figure 4 shows what might happen to apartment temperatures in our sample building if an EMS were installed and the distribution system were balanced. Note the much smaller range of temperatures between the hottest and coldest apartments (4°F maximum), and no significantly overheated apartments. Achieving maximum savings with an EMS can only be realized in conjunction with balancing the distribution system.

Predicting Energy Savings

To calculate potential energy savings, you must first estimate and enter the reduction in average building temperature into the building energy model. In a recent study of mid-rise steam and hot water heated buildings, energy management systems were successful in reducing average building temperatures in twelve out of fifteen buildings.[1] The average reduction in building temperature was 2.5°F for steam-heated buildings and 0.6°F for hot water heated buildings (Table 1). However, even when the boilers were controlled by EMSs, between 67% and 100% of the apartments in each building were found to be overheated. As expected, there was a strong positive correlation between how overheated a building was without the EMS operating and how much the average temperature was reduced by turning on the EMS. That is, buildings with the highest average temperature when the EMS was deactivated had the largest reduction in average building temperature when the EMS was reactivated.

The study did not track fuel consumption, so heating fuel and cost savings results must be extrapolated. A U.S. Department of Energy publication from 2013[2] stated that overheating increases annual heating energy consumption by approximately 3% per degree Fahrenheit per day. Using this DOE estimate

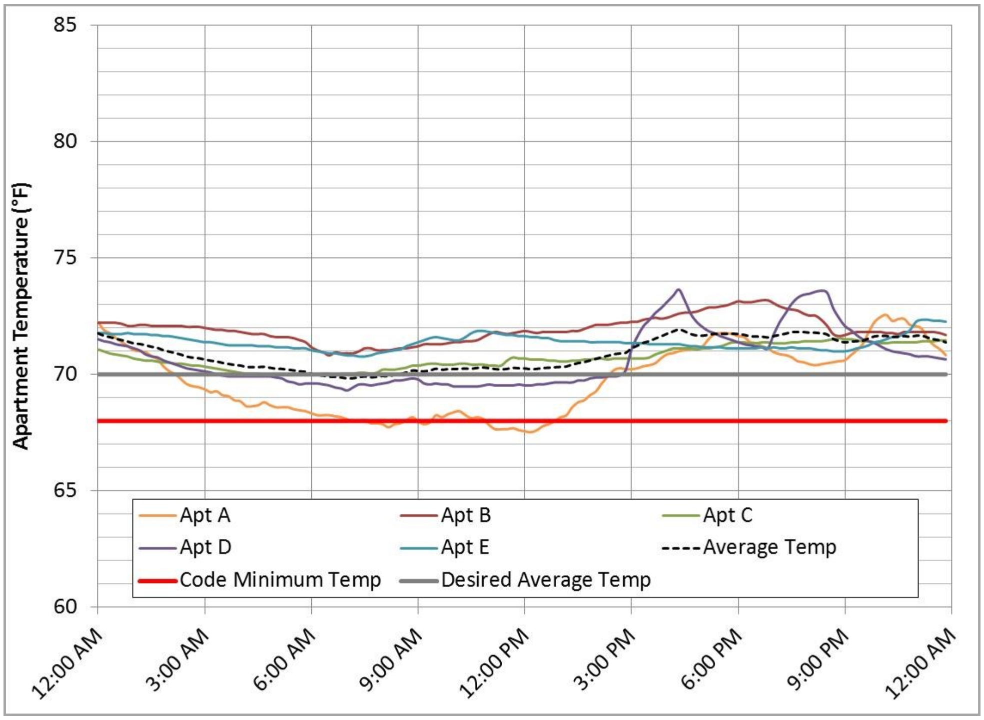


*Figure 4: Temperatures in our sample building adjusted to show what is likely to happen when an EMS is installed **and** the distribution system is balanced.*

	Average Reductions in Building Temperature			Number of Buildings
	Average	Minimum	Maximum	
1-Pipe Steam	2.5°F	-0.5°F	5.9°F	12
Hot Water	0.6°F	-1.6°F	2.6°F	3

Table 1: Reductions in building temperature achieved when the EMSs were activated.

and the average temperature reductions found by Dentz, et al., 7% heating energy savings for steam buildings and 2% savings for hot water buildings are likely when an EMS is installed in a building. EMS manufacturers predict at least 10% heating energy savings, which they claim is conservative, from upgrading boiler controls from an outdoor reset to an EMS. Compared to the temperature reductions achieved by Dentz, et al., 10% heating energy savings should not be considered a conservative estimate but it may be useful instead as an upper limit for achievable savings.

[1]Dentz, J., Varshney, K., and Henderson, H. (2013). Overheating in Hot Water- and Steam-Heated Multifamily Buildings. The full text of this study is available online in the Building America Program Publication and Product Library.

[2]U.S. Department of Energy. (2013, 11 26). Thermostats. Retrieved 1 9, 2014, from Energy.gov: http://energy.gov/energysaver/articles/thermostats-and-control-systems

Modeling Protocols for Implementing EMS on Heating Systems in Multifamily Buildings

The following modeling protocols are intended to help energy modelers accurately and conservatively calculate potential savings from implementing Energy Management Systems on steam and hot water systems.

STEAM SYSTEMS		
Existing	**Proposed**	**Modeling Protocol - Steam**
On/off control only; no outdoor reset Note that outdoor reset for steam systems is defined as a control that adjusts the length of the steam cycle as the outdoor temperature changes.	Outdoor reset	Model as a temperature reduction. Do not model "outdoor reset" as this option only applies to hot water system or vacuum steam systems. Must provide details of existing controls and evidence that outdoor reset is not currently being utilized. 1°F maximum temperature reduction
Outdoor reset; heating imbalances observed	EMS with indoor temperature sensors; distribution imbalances not addressed	2°F maximum temperature reduction
Outdoor reset; heating imbalances observed	EMS with indoor temperature sensors; distribution balanced	3°F maximum temperature reduction
Outdoor reset; no heating imbalances	EMS with indoor temperature sensors	3°F maximum temperature reduction

HOT WATER SYSTEMS		
Existing	**Proposed**	**Modeling Protocol – Hot Water**
On/off control only, no outdoor reset	Outdoor reset and EMS with indoor temperature sensors	Model as outdoor reset control on hot water loop. Must provide details of existing controls and evidence that outdoor reset is not currently being utilized. System must be able to operate with outdoor reset (condensing boilers and/or boilers separated from heating loop). Additionally, model a temperature reduction of 1°F maximum if the outdoor reset curve (i.e. the hot water loop set point) will be adjusted based on feedback from apartment sensors.
Outdoor reset	EMS with indoor temperature sensors	Model as a temperature reduction if outdoor reset curve (hot water loop set point) will be adjusted based on feedback from apartment sensors. 1°F maximum temperature reduction

Note: Steam boilers that supply a hot water loop are to be considered a hot water system.

Best Practices to Achieve Savings

Energy management systems can reduce heating energy use in multifamily buildings. Taking the following steps will help maximize savings.

1. Identify pre-existing temperature control problems. Measure and record building temperatures in a variety of apartments during the heating season. Interview the superintendent, manager, owner, and residents to gain an understanding of heating issues in the building.
2. Evaluate loads on the building. Determine whether there are other factors causing the apartments to be over- or under-heated such as solar loads, wind loads, removed or oversized radiators, etc.
3. Gain a general understanding of the distribution system layout. Then look for patterns in heating imbalances.
4. Consider implementing comprehensive rebalancing if heating imbalances are observed. Savings will be limited without rebalancing.
5. Identify all components of the existing boiler control system. Make sure that the existing controls are unable to provide indoor temperature feedback. Determine whether night setback and outdoor reset controls are in place.
6. Model predicted savings using the modeling protocols above.
7. Review the plan for the new controls, including a careful examination of sensor locations, set points, and zones. Ensure that the proposed EMS provides a significantly different control strategy than the old control system; otherwise, savings will not be achieved. In 2-pipe and hot water systems, sensors should be installed in no fewer than 10% of apartments and on a variety of floors and in a variety of apartment lines. In 1-pipe steam systems, sensors should be installed in no fewer than 25% of apartments and on a variety of floors, and there must be a sensor in the apartment at the end of each steam line.
8. Inspect the installation. Ensure that the sensors are located in apartments that represent average building temperatures and that they are installed on interior walls, out of direct sunlight, and away from sources of drafts or heat.
9. Review the EMS settings; make sure they have been adjusted to reflect the needs of the building. Note that in general, the target setpoint for the EMS will need to be several degrees warmer than the minimum temperature required by code to ensure that the coldest apartments meet code. If you are working in a building where tenants are likely to resist a temperature change, consider reducing the temperature slowly, across several months. Also consider adjusting the temperatures seasonally, to be warmer in deep winter and cooler in the fall and spring.
10. If balancing work was performed, create a plan for continued maintenance. Train building staff on how to maintain the distribution system.
11. Train staff thoroughly on how to properly operate the new EMS, or consider restricting their access to the controls. If the building does not currently have a protocol for addressing tenant heating complaints, develop one that involves correcting all other potential reasons for low temperatures before turning up the EMS setpoints. Emphasize that staff should not override the system or increase the temperature in the whole building just because of a single tenant complaint.

Conclusion

Energy management systems can be an effective tool for reducing the high average temperatures often found in multifamily buildings and they can lead to substantial energy and cost savings. It is important, however, to understand the capabilities and limitations of EMS controls. EMSs cannot correct temperature differences in apartments that are caused by heating system imbalances; as a result, the overall temperature reduction possible in a given building is limited by the temperature of the coldest apartments. In order to maximize savings, comprehensive balancing work must be performed in conjunction with an EMS installation.