Chapter 5: *Measures to reduce heating fuel consumption*

About 40% of the energy we use to heat and cool our homes is wasted.[104] Chapter 5 focuses on improvements to buildings we can make to reduce fuel consumption. This includes oil, natural gas or steam used for heating and hot water purposes. What building owners should ensure right away is that the heating system is well tuned with the help of a combustion efficiency (CE) test.[105] Regular maintenance and fine-tuning of the burner and boiler to run at maximum efficiency can save thousands of dollars at very low cost.

Insulating all the pipes carrying hot water and steam in the boiler room and throughout the building where they are accessible will also provide instant savings. The boiler itself should be wrapped in insulation as well. Maintaining radiator steam traps and shutoff valves is also critical and should result in considerable fuel savings. In one-pipe radiator systems, the system should be vented throughout the building.

Furthermore, the building owner or manager should hire an energy efficiency specialist or a New York State Energy Research and Development Authority (NYSERDA) partner (see list in Appendix E) to perform an energy audit and identify efficiency measures. Most of these efficiency investments have a very short payback period and can save up to 40% in fuel consumption, depending on the building's current efficiency level. The chart at the end of this chapter summarizes the different measures that can help reduce heating fuel consumption.[106] For more details about efficiency measures that help reduce a building's electricity consumption, please refer to chapter 6.

Improved boiler and distribution system controls for reduced emissions

All boilers require some form of active control to determine how long they should fire and when. For a variety of reasons, most controls currently in use are quite primitive compared to what is available, and improved controls are one of the most straightforward ways to reduce fuel use and emissions. The building's heating system maintenance company should perform an annual combustion efficiency test, which shows whether the heating and hot water system is running at maximum efficiency.[107]

It is also important that the heating system operator (typically the superintendent) monitors the heating system daily and keeps a log that the managing agent reviews. Three simple devices that each cost around $100 will give the operator important information about whether the boiler and burner are operating efficiently. The following devices should be installed in a building:

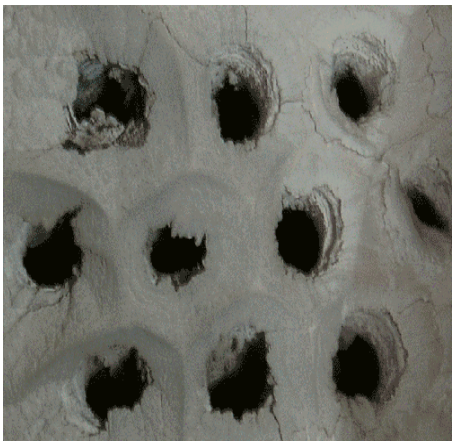
- Permanent stack thermometer (high stack temperatures are an indicator of inefficient combustion)
- Makeup water meter (indicates if water level is stable in boiler or if a lot of makeup water is needed, which means that steam is leaking somewhere)
- Domestic hot water temperature sensor (buildings should avoid overheating the domestic hot water to avoid scalding accidents and to save fuel)

The following section presents several useful upgrades to boiler and heating system controls.

Maintenance first—proper maintenance can bring over 20% fuel savings

A great deal of fuel is wasted because operators can be penny-wise and pound-foolish on the topic of maintenance. Proper maintenance is important in the boiler room and in residents' apartments. The boiler room operator should ensure that the boiler fire tubes are kept clean to ensure maximum efficiency. The heat transfer loss in dirty boiler fire tubes rises tremendously as the layer of soot builds up.

Dirty boiler fire tubes



Clean boiler fire tubes

Boiler efficiency can be monitored through daily stack temperature readings with the help of a permanent stack thermometer. For every 40°F rise in stack temperature, fuel consumption increases by 1%. An increase in stack temperature is an indication of dirty tubes and a signal to clean the boiler fire tubes.

Correctly functioning steam traps and air valves are vital to the efficient operation of steam distribution systems, which should be checked annually or when complaints occur, and replaced as needed. Radiators in hydronic systems should be bled annually to remove air. Poorly functioning radiation can result in cold spaces, which then result in overheating the rest of the building. Properly functioning steam traps and air valves can reduce heating fuel use by up to 20%. Maintenance is obviously very important.

Steam trap on steel radiator.

Thermostatic radiator valves and shutoff valves can bring between 3–20% fuel savings

Thermostatic radiator valves (TRVs) allow heat to flow to individual radiators only when the room temperature is below an adjustable set point. Placing TRVs in overheated rooms will redirect the boiler's heat to rooms where it is needed, permitting the overall setting to be dialed back as windows are closed in the overheated areas. TRVs can yield between 3–20% in fuel savings (see case study that follows).

TRVs cost $60 to $100, plus installation, and the main manufacturers are Danfoss and Honeywell. If this is too expensive, simple shutoff valves should be installed, if not already present, so that residents and tenants have the option of turning off a radiator if a room gets overheated. Opening windows is not an advisable way to control the room temperature. Although the cost of installation exceeds the cost of the TRV, if no valves are present, the extra cost of TRVs over shutoff valves is quite small. If TRVs are nevertheless too expensive, each radiator should be equipped with a working shutoff valve.

TRVs are quite effective with two-pipe steam and in hydronic systems that are plumbed with parallel pathways so that the valve on one radiator cannot turn off the hot water to all the other radiators. (If the hydronic system is plumbed "in series," TRVs cannot be used without substantial additional piping. Also, with a hydronic system, the circulation pump must be driven by a variable speed motor that can lower the flow rate if many TRVs shut off their radiators.)

TRVs are also available for one-pipe steam systems. In this case, they replace the air valve and do not let air out of the radiator unless the room temperature is below the set point. In theory, if the air can't get out, the steam can't get in. In practice, many one-pipe systems are run at steam pressures that are much higher than necessary and the TRV has little effect because the steam will force its way into the radiator. This highlights the importance of proper training for all building operating personnel—the boiler pressure should be kept at the lowest value possible, normally in the range of 1–2 pounds per square inch (psi) whether or not there are TRVs installed, since any pressures above this compromise both efficiency and human safety (because of high radiator temperatures).

TRV on cast iron radiator with temperature sensor directly attached to TRV which is not ideal

TRVs come in two styles. In the first type, either the temperature sensor or dial are directly attached to the valve when there is no radiator cover (see picture to the right). If the radiator is enclosed, it is recommended to mount the temperature sensor on a nearby wall and connect it to the valve by a thin tube.

TRV with control outside of the radiator cover.

The second type (known as a "remote actuator") is better under all circumstances and must be used if radiator covers are present, because it is important that the actuator sense room temperature rather than radiator temperature. The picture on the left shows a TRV that can be controlled from outside the radiator cover.

Tenants and owners must make sure that all radiator covers can open up to give maintenance staff easy

access to the steam traps, the radiator shutoff valves or the dial part of the TRV. Building rules should mandate accessible radiator covers, making proper maintenance possible.

Improper radiator and HVAC replacements

In a residential setting, apartment owners upgrading their homes might install new, esthetically appealing radiators that are undersized for the space. For example, lightweight steel cannot provide the same heat as cast iron in a steam system. Building owners should have clear policies on responsibilities in this situation and should refuse to overheat buildings to maintain temperatures in cases of inappropriately resized radiation.

Modulating aquastat (hot water boilers only)

A modulating aquastat controls the temperature of the water in the boiler, much like a thermostat controls the temperature of the air in the room.

Typically, boiler water temperature in a hot water boiler is kept at approximately 180°F. In the spring and fall, less heat is required and the boiler water temperature can be reduced, usually to around 120°F.[108] A modulating aquastat senses the outdoor ambient temperature and adjusts boiler water temperature accordingly. Aquastats usually have a sensing bulb that is installed in the side of the boiler to monitor the boiler temperature and a thermometer mounted on the exterior of the building. Modulating aquastats can lower annual fuel costs by approximately 10%, depending on heating needs.

Aquastat units cost approximately $100 to $300 and professional installation is usually required. [109]

"If a condensing boiler is used for hydronic space heating, a modulating aquastat (sometimes called a "reset" system) is absolutely necessary to permit the condensing capability of the boiler to function. On the coldest days, the system will call for 180°F water and the condensing function will operate minimally, if at all, and efficiency will be relatively low. But on shoulder[110] and warmer days (roughly 40oF and higher), the heating load will be low and distribution temperature can drop dramatically, allowing the condensing function to operate and efficiency to rise well above 90%.

Programmable thermostats can save up to 15% in fuel

Preprogrammed Energy Star thermostat settings (heating)

Setting	Time	Set-point Temperature
WAKE	6:00am	≤ 70°F
DAY	8:00am	Setback at least 8° F
EVENING	5:00pm	≤ 70°F
SLEEP	10:00pm	Setback at least 8° F

Source: Energy Star

A thermostat monitors the temperature of one or more areas within a building and initiates or terminates boiler operation, depending on heating needs. Most older thermostats have only one setting—which must be changed manually. A programmable thermostat allows the building owner to specify multiple set points that can vary by time of day. The heating system will then

respond to thermostat commands by providing more or less heat as required—for example, by turning the heat down at night when most people are sleeping and turning it up again before they wake in the morning.

Programmable thermostats usually have the capability to specify different temperatures for up to four time periods daily: wake, day, evening and sleep.

The U.S. Department of Energy's Energy Star program recommends that temperatures in most residential buildings be set back at least eight degrees during the day and night (sleep), compared with temperatures first thing in the morning (wake) and evening, when most family members are in the house.

Fuel cost savings can equal as much as 1% for each one degree of temperature setback for a period of eight hours or longer.[111] If the temperature can be set back at least 8° F for eight hours daily, one can expect a savings of approximately 5–15% annually.

Programmable thermostats can cost anywhere from $35 to $400 depending on installed features.[112] Installation requirements depend on the details of the current thermostat installation; generally a registered electrician should perform the installation of a new programmable thermostat. These systems can be used in single-family and multifamily homes and small apartment buildings. They may not be practical in very large apartment buildings.

Programmable thermostat set for 55 deg. F. while home unoccupied. .

Programmable thermostats in smaller buildings

Boilers in most smaller buildings (one to four-family houses) are controlled by simple thermostats that turn the boiler and circulation pumps (if used) on and off to maintain internal temperatures within a degree or two of a set-point temperature. Significant savings can be achieved in these buildings by installing a programmable thermostat that can be set to lower temperatures at times when the building is not occupied or people are sleeping.

In single-family homes and smaller buildings, one should consider lowering the temperature set point to 68–70°F or lower for quick savings. Older furnaces and boilers should be replaced with efficient Energy Star models for more permanent savings with a longer payback period.

Boiler controls in larger buildings can save approximately 15% in fuel (using energy management systems)


Heat-Timer; www.heat-timer.com

In larger buildings, almost all steam boilers and many hydronic systems are controlled by a very different system than in small building systems. A company called Heat-Timer dominates the market, although competitive manufacturers do exist. In most buildings, these control systems are mostly designed to make it easy to comply with

New York City heating laws rather than make the system most efficient and comfortable for the residents. In all but the most expensive models, these boiler controls ignore interior building temperatures and, each hour, determine how many minutes the boiler should fire solely based on the outdoor temperature (which they measure directly with a remote thermometer). The building operator can make the firing time longer or shorter for a given outdoor temperature by choosing one of several preset response functions, but once this is done there is no compensation for whether a day is windy, sunny or humid.

Most building operators will increase the response curve until the coldest (or loudest) resident stops complaining on cold days. The result is a building that is overheated most of the time and in which many residents will regulate the temperatures in their apartments by opening windows. Underlying this situation, of course, is needless consumption of heating fuel.

There is a straightforward upgrade that can lower fuel consumption by 10–15% by improving this aspect of boiler control alone. Known either as an "energy management system" (EMS) or "building management system" (BMS), a boiler control system can include a set of temperature sensors (remote thermometers) scattered throughout the building and use this information as the primary determinant of how long the boiler should fire.[113] These systems are actually computers with remote operations capability, allowing much greater flexibility and increased knowledge of system performance so that savings accrue from, for example, advance warning of system failures, as well as from reduced fuel use.

An EMS will normally only regulate the boiler for the purposes of making domestic hot water (DHW) and providing heat. EMSs are primarily used in multifamily residential buildings. A BMS is a more complex system and will provide integrated control of most or all building equipment, including fire and security alarms, pumps, elevators and other equipment, as well as heat and DHW. BMSs are more common in larger commercial buildings (see also http://www.htcontrols.com).

An EMS can cost from $8,000 to $20,000 and will produce savings of at least 10% and often more, resulting in payback periods of 1–5 years on the basis of fuel savings alone (depending on building size).

This ENERGUARD™ Control System (EMS) is a wireless computerized climate control system designed for small- to large-sized residential apartment buildings, commercial office buildings, schools and industrial plants. Typical energy savings range from 15% to 50% with payback ranging from 1 to 2 years (see http://www.ec4h.com/divisions/Energy/ENERGUARD1.pdf).

Two manufacturers of EMSs are PEPCO http://pepcocontrols.com/index2.html) and Heat-Timer (http://www.heat-timer.com). Heat-Timer has an "MPC Platinum" model with internal temperature sensors, which is still something of a specialty item. Intech-21 (www.intech21.com), OAS (www.oasincorp.com), and U.S. Energy Group (www.use-group.com) also install and supply EMSs.

Heating system balance issues

Even with an EMS or BMS providing improved control, building operators frequently find that some spaces will be perennially overheated, while others will be cold. Since this will usually result in substantial overheating to keep the coldest spaces comfortable, significant savings can be realized by improving the system balance. Balance can only be addressed by using TRVs (discussed above) and zone controls.

Zone controls

Often there are large discrepancies in how much heat is needed in different parts of a building, especially between the south and north sides of a building on sunny winter days. The best way to control for this is to break the heat distribution system into "zones" so that heat can be sent only where it is needed. Ideally a large building will be divided into two to four or six zones, all controlled by an advanced EMS with multiple temperature sensors. Unfortunately, most New York City residential buildings were designed with only a single zone. Converting a large single zone system to multiple zones is a complex job that must be managed by an experienced heating engineer. A 23-story prewar building on the Upper East Side improved its fuel costs by 18% when different zones were set up and the heating was managed by an advanced Energuard EMS.[114] Zone controls can be used with either steam or hydronic distribution systems and with or without TRVs.

Reducing boiler loads by taking simple steps

Ensuring that the boiler and distribution system are working well will minimize emissions and fuel use for the loads imposed by the building. Another, equally cost-effective way to decrease emissions and fuel use is to reduce the loads of the building itself, meaning that less oil is needed to heat the building or produce hot water. The three main areas for reducing building loads are reduced infiltration of outdoor air, improved insulation against thermal losses and reduced consumption of hot water.

Stack effect

In winter, a tall building acts like a chimney. The warm air inside is lighter than the cold air outside and tends to rise, pulling cold air in through any openings near the ground and discharging heated air through any openings on or near the roof. In most buildings, this flow of air is substantially greater than that needed for adequate ventilation and constitutes a large and wasteful load on the heating system. A variety of techniques can be used by professionals to identify and isolate leaks, ranging from smoke pencils that track drafts to blower doors that are used to pressurize entire small buildings. Even without this information, however, active steps to reduce infiltration are well worthwhile. Because many aspects of building construction contribute to infiltration, there are many separate steps that can be taken to reduce it, and the simplest are presented here.

Wall and pipe insulation can reduce heating costs by about 20%

What building owners should do first is insulate all the exposed pipes in the boiler room and throughout the building. The boiler itself should also be wrapped in insulation material to minimize heat loss. Everything that feels warm to the touch should be insulated. When a resident or the building owner performs repairs that require the walls to be opened up, the building management should take that opportunity to insulate all

the pipes carrying steam and hot water, pushing insulation up and down into the adjoining floors.

Air-sealing measures like high-endurance caulking and spray-foam applications also reduce energy use and expenses and improve the comfort of the building interior.[115] In addition to airflow, heat leaks out of buildings by conduction through walls, windows and any other surface in contact with the outdoors. Blowing insulation into the walls of wood-frame structures is a cost-effective measure, but is not usually practical for masonry or steel-frame buildings. (Although it can be effective if there is a roof cavity that can be filled.) In large buildings with radiators, a substantial part of the heat released by the radiator is directed into the wall behind it and a sizeable part of that is lost to the outdoors. If it is esthetically acceptable, a slab of insulation between any radiator and the wall behind it will be a very cost-effective intervention.

Weather-stripping and caulking of windows and doors


Weather-stripping of doors and windows

Weather strip on doors and windows becomes tattered and leaky over time and should be examined annually and replaced when worn. Window frames can become leaky, especially in wood-frame buildings, and should be recaulked whenever leaks are noticeable. If window sashes and gaskets become loose and leaky in their tracks, replacement may be justified, but one should consider the insulating value of new double-glazed windows (discussed below).

If the windows are still in reasonable shape and street noise reduction is also a concern, then the existing windows can be weather-stripped (replacing gaskets and seals, recaulking) and interior windows can be installed, which reduces noise and draft by more than 90%.

Replacing windows

Double-glazed windows transmit less than half the heat of single-glazed windows; any single-glazed window can be replaced and will pay for itself in eight to twelve years. Replacement of older double-glazed windows is not cost effective based on the reduction in conduction losses, even though new windows will be better, but the savings will effectively reduce the cost of the replacement if it must be carried out. If windows are to be replaced, one should choose Energy Star windows whenever available.


Double-glazed exterior and interior windows

In New York City high-rise buildings (and most other cities), wood-frame and vinyl-frame windows are not acceptable because of fire hazards. The standard until recently has been to use aluminum-frame windows

with "thermal breaks" to reduce heat loss through the frame.

The thermal performance of these aluminum windows lags substantially behind wood or vinyl, and a superior alternative is now available: windows with fiberglass frames provide fire resistance equal to or better than aluminum and thermal properties comparable to vinyl, transmitting 30–50% less heat than aluminum-framed windows. Because they are only now penetrating the market, it may take a little more work to find an installer familiar with fiberglass-frame windows, but the lifetime performance difference makes the shopping effort well worthwhile. To keep cold air out in the winter and warm air out in the summer, the new windows should be purchased with a low emissivity film (e-film), which will further help reduce air-conditioning needs in the summer and heating needs in the winter.

Doors

In larger buildings, entry doors can be the source of substantial infiltration. Revolving doors are an excellent solution, but are not popular in a residential setting. Many buildings were designed with entry foyers with doors at both ends of the foyer, and many buildings have removed the interior doors for esthetic reasons. The result is a large blast of cold air every time the outer door is opened. Building owners should consider installing or replacing interior doors, at least for the duration of winter. In older buildings, there may be stairwells rising all the way to the roof that are open to the first floor hallway. This invites upward airflow and if at all possible, the stairwell should be broken by a doorway one or two flights up, if not at the ground level.

Window A/C program

Window A/C unit

Window air conditioners are ubiquitous in New York City and because of the shortage of storage space and the effort involved in installing them, a great many of these air conditioners remain in the windows year-round. Since they are not well sealed, a large amount of air leaks in or out around them for the entire winter, driven by the pressures induced by stack effect. Anything building management can do to encourage or mandate removal and storage of air conditioners will have a direct and positive effect on fuel consumption. The precise mechanism will depend on the ownership structure of the building and other factors, but must at a minimum include safe winter storage to facilitate compliance.

Elevator and stair roof sheds

By law, the roof sheds at the top of elevator shafts must include openings to permit the escape of smoke in the event of fire. In most buildings, this requirement is met by simply leaving substantial openings that encourage the flow of warm air up the elevator shaft and out. Fire department requirements can be met by sets of normally closed louvers, which are motorized and attached to smoke detectors and the building's fire alarm

system so that they will open in the event of a fire. Closing the openings and installing a controlled set of louvers is a worthwhile investment for any building that currently has permanent openings.

Domestic hot water (DHW)

Most hot water in New York City is produced using the same fuels as space heat and reduction in hot water use will also reduce fuel use and emissions. In the residential area, the most obvious steps involve the use of flow restrictors in sinks to limit flow to 1.5 gallons per minute (gpm) and limit showerheads to 2–2.5 gpm. (High quality showerheads at this rate give a perfectly comfortable shower.) The use of dishwashers should be encouraged, as they make much better use of hot water than does washing dishes by hand. Whether clothes washing takes place in apartments or in a laundry room, Energy Star and/or front-loading washing machines will use substantially less hot water than standard appliances.

Commercial buildings don't normally use large amounts of hot water unless they involve food preparation or laundries. Commercial rest rooms should make use of the same low-flow fixtures as residences. Commercial kitchens will save substantial amounts of hot water (and cold water and electricity) by following the Energy Star recommendations (www.energystar.gov, "Products," "Commercial Kitchens").

Summary of heating system efficiency measures	
Efficiency Measure	**Approximate Fuel Savings**
Keep heating and hot water systems well maintained with regular boiler tube cleanings and yearly combustion efficiency tests. Adjust air/fuel ratio for increased efficiency. Maintain well-functioning steam traps, air valves and shutoff valves on all radiators.	20% or more
Three low cost items (around $100 each) that will help save fuel and give heating system operators daily important information as to heating system efficiency are: • Permanent stack thermometer • Makeup water meter • Domestic hot water temperature sensor	Varies
Install thermostatic radiator valves or radiator shutoff valves (low-cost investment and increased resident comfort).	3-20%
Install an energy or building management system (EMS/BMS) that takes indoor air temperature into account for heating control.	15-25%
Use an EMS/BMS and zoning system (creating different heating zones in a building).	20% or more
Install a programmable thermostat (in smaller buildings).	15%
Control pump-recirculating domestic hot water with an aquastat (senses and controls water temperature, just like a thermostat does air).	Varies
Put in wall and pipe insulation (whenever pipes are accessible).	20%
Require residents to use properly sized radiators to avoid underheating or overheating. Also require all radiators to be accessible for maintenance purposes.	Varies
Weather-strip and caulk windows and doors.	Varies
Replace single-glazed windows with double-glazed windows and low-emissivity coatings and argon gas fill.	Varies

*) The savings indicated are for each measure in isolation. Installing any one measure (e.g. TRVs) lower the potential savings of others (e.g. EMS).

Financing and financial incentives

The New York State Energy Research and Development Authority (NYSERDA) offers various financing programs that can help building owners pay for an overall "Energy Reduction Plan" based on an energy audit. The web of financial incentives that support energy efficiency improvements can be complex, so NYSERDA partners can help owners through this process. A list of NYSERDA partners can be found at www.getenergysmart.org/Resources/FindPartnerDetails.aspx?co=62, and Appendix E of this report includes a NYSERDA list as of April 2009. These NYSERDA partners can help find funding and guide housing communities through the application process to ensure that all opportunities are taken advantage of. For example, funding is provided through NYSERDA's Multifamily Performance Program (MPP), which helps communities obtain reduced-rate Energy Smart loans and incentive grants, including:[116]

- $5,000 per unit up to $2.5 million per borrower in loans with reduced interest rates up to 4% below market rate
- Up to $2.5 million in additional loans for work-scope-qualified projects
- Two interest rate reductions for loans up to $5 million for public housing authorities that combine multiple properties into one energy efficiency improvement project
- Up to a $10,000 incentive at the beginning of the project
- Up to $1,200 in additional incentives per unit as the project progresses

In New York State and within the Con Edison service territory, ratepayers are eligible for a wide variety of energy services from NYSERDA (see www.nyserda.org and www.getenergysmart.com for residential programs). Funding is available to help pay for energy audits by qualified professionals and to help buy down the capital cost of energy-efficient equipment. Although the web site can be confusing, substantial help is available and it is well worth the time of anyone considering serious energy efficiency upgrades.

NYSERDA's partner companies can also help develop a financing strategy, including applying for a loan through the New York Energy $martSM Loan Fund (www.nyserda.org/loanfund). This program provides an interest rate reduction off a participating lender's normal loan interest rate for a term up to ten years on loans for certain energy-efficiency improvements and renewable technologies.

In addition, the web site of the American Council for an Energy-Efficient Economy (www.aceee.org) provides a great deal of useful data and guidance.

For more financial incentive details, refer to the following web link: http://www.getenergysmart.com/MultiFamilyHomes/ExistingBuilding/BuildingOwner/Financing.aspx.

For low-income housing, refer to the following web link:
http://www.getenergysmart.com/LowIncome/HomeOwners.aspx

For existing multifamily buildings (five or more units,) refer to the following web link: http://www.getenergysmart.com/MultiFamilyHomes/ExistingBuilding/BuildingOwner/Participate.aspx. Also go to www.getenergysmart.com, select "Multifamily 5+ units" on the left, then "Existing Buildings," then "Building Owner/Manager." There are several sections and the "Financing" part explains how the incentives and the loan funds work.

To find a NYSERDA certified contractor refer to the following web link:
http://www.getenergysmart.org/Resources/FindPartnerDetails.aspx?co=6