The bottom of the barrel

HOW THE DIRTIEST HEATING OIL POLLUTES OUR AIR AND HARMS OUR HEALTH

December 16, 2009

ENVIRONMENTAL DEFENSE FUND
Finding the ways that work

urban green
U.S. GREEN BUILDING COUNCIL
NEW YORK

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Our mission
Environmental Defense Fund is dedicated to protecting the environmental rights of all people, including the right to clean air, clean water, healthy food and flourishing ecosystems. Guided by science, we work to create practical solutions that win lasting political, economic and social support because they are nonpartisan, cost-effective and fair.

The complete report is available at www.edf.org/dirtybuildings.

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Executive summary[1]

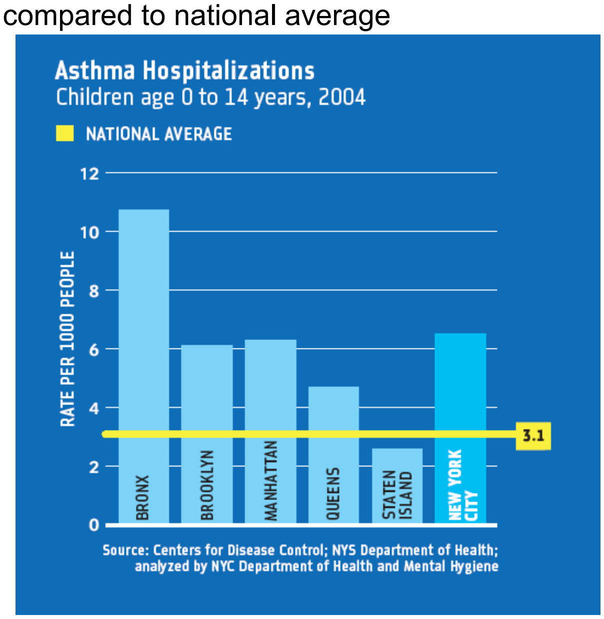
The problem

San Remo building spewing out black smoke from burning No. 6 oil (unrefined sludge)

New York City's air fails to meet health-based National Ambient Air Quality Standards (NAAQS) for soot and ozone.[2] Not surprisingly, the American Lung Association's (ALA) 2009 State of the Air report gives New York City a failing grade in terms of air quality.[3] The ALA report cites new research showing that ozone and fine particle pollution ($PM_{2.5}$) are extremely dangerous to public health. Soot and ozone pollution is unhealthy, takes the lives of infants and alters the lungs of children. The risks of air pollution are greater than we once thought.[4]

Still, black smoke pouring out of large New York City buildings is a common sight. These buildings' heating systems spew toxic soot, heavy metals (nickel) and other pollutants into the air because they are burning unrefined sludge (referred to as residual fuel or No. 4 or 6 oil).[5] Close to 9,000[6] large residential, commercial and institutional buildings currently burn this type of fuel, which contributes considerably to the city's air pollution and impacts public health.[7] For example, a new study shows that nickel-laden soot pollution is associated with respiratory symptoms in young children.[8] These sludge-burning buildings – which represent 1 percent of the city's buildings – contribute 86 percent[9] of the city's heating oil soot pollution which is more soot pollution than comes from the city's cars and trucks. Overall, residential, commercial and institutional heating systems release 50% more soot (PM)[10] and 17 times more sulfur dioxides (SO_2) than cars and trucks on New York City's roads.[11,12]

Figure 1: NYC asthma hospitalization rates compared to national average



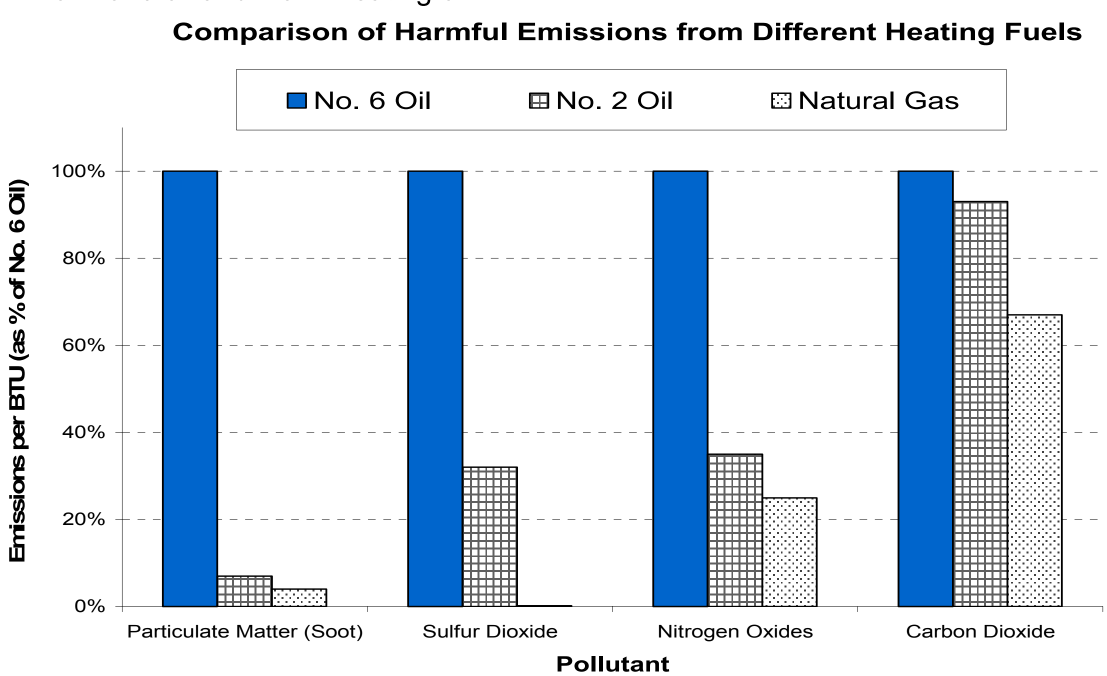
Federal, state and local governments have enacted measures to reduce emissions from the on-road and off-road sectors. This is because of widespread awareness that $PM_{2.5}$ emissions have been linked to aggravated asthma, cancer, lung and heart disease and premature death; and, that New York City has twice the national asthma hospitalization rate among children 0–14 years. Air pollution exacts a high price for New Yorker's health and taxpayers' money. For example, in 2000, New York City asthma hospitalizations alone cost government and individuals more than $240 million a year.[13] Medicaid and Medicare paid about 72% of these costs.

In addition, the soot pollution spewed out in disproportionate amounts by buildings burning No. 4 or No. 6 oil not only contributes to unhealthy air but also to climate change. Recent studies have shown that soot pollution (black carbon) is the second-largest contributor (after CO_2) to climate change. So reducing soot pollution will also have an immediate impact on mitigating climate change.[14]

The heating oil sector has been entirely ignored by the federal government and largely remains neglected by the state government, which has not yet acted on various proposals to make its sulfur caps protective enough for public health.[15,16] Nevertheless, the city has left this air pollution problem unaddressed. Air pollutants from No. 4 and 6 heating oil boilers are uncontrolled, contribute to unhealthy air quality and are a quality of life issue when New Yorkers open their windows to let in "fresh" breezes.

Switching from No. 6 oil to No. 2 heating oil reduces PM emissions by about 95%, SO_2 by about 68% and nitrogen oxides (NOx) by about 65%. Switching from No. 6 oil to natural gas reduces PM emissions by about 96%, SO_2 by over 99% and NOx by about 75%. In terms of global warming pollution, switching from No. 6 oil to No. 2 heating oil reduces heat-trapping CO_2 emissions by about 7%, and natural gas reduces CO_2 emissions by about 30% compared to No. 6 oil.[17] Switching to No. 2 heating oil or natural gas will also eliminate harmful nickel emissions as No. 4 and 6 oil spew out high levels of toxic nickel. Not surprisingly, New York City's nickel levels are on average nine times higher than average nickel levels in other U.S. cities. Nickel is a metal that when airborne has been linked to cardiovascular disease and premature death.[18]

Figure 2: This Figure depicts the dramatic difference in pollutants generated by No. 6 oil compared to No. 2 heating oil or natural gas. No. 4 oil is typically a 50/50 mix of No. 6 oil and No. 2 heating oil.



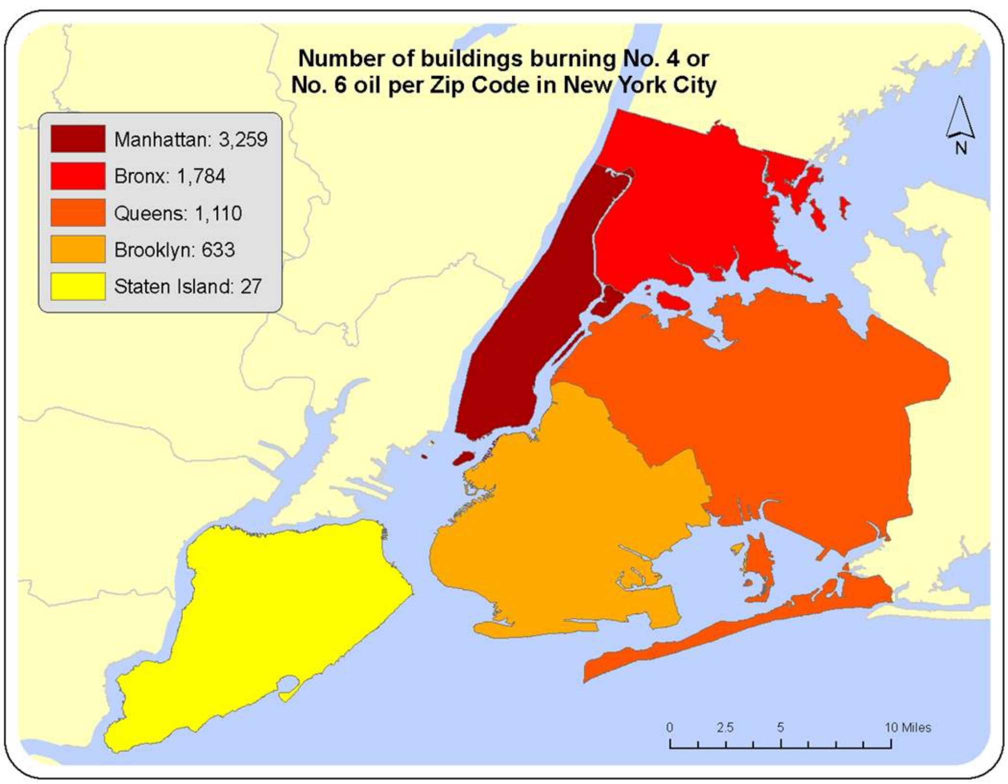
The problem is so urgent that it requires a clear phase-out schedule to ensure that these buildings are no longer allowed to burn No. 4 or 6 oil. The following steps should be taken by promulgating a new Dept. of Environmental Protection rule: a) new real estate developments as well as buildings currently burning No. 2 heating oil should be denied permits for No. 4 or No. 6 oil, b) develop a phase-out system for existing boilers/burners that burn dirty fuels with a variance procedure for low income buildings to give them enough time to switch to natural gas, and 3) devise ways to help New Yorkers transition to cleaner, greener fuels.

In addition, to facilitate the needed conversions, the city should work with the New York State Energy Research and Development Authority (NYSERDA) to develop conversion incentives especially for low income buildings presently burning No. 4 or 6 oils. The city should also coordinate with Con Edison and National Grid to establish the needed natural gas infrastructure.

Locations of NYC buildings that burn dirty fuel

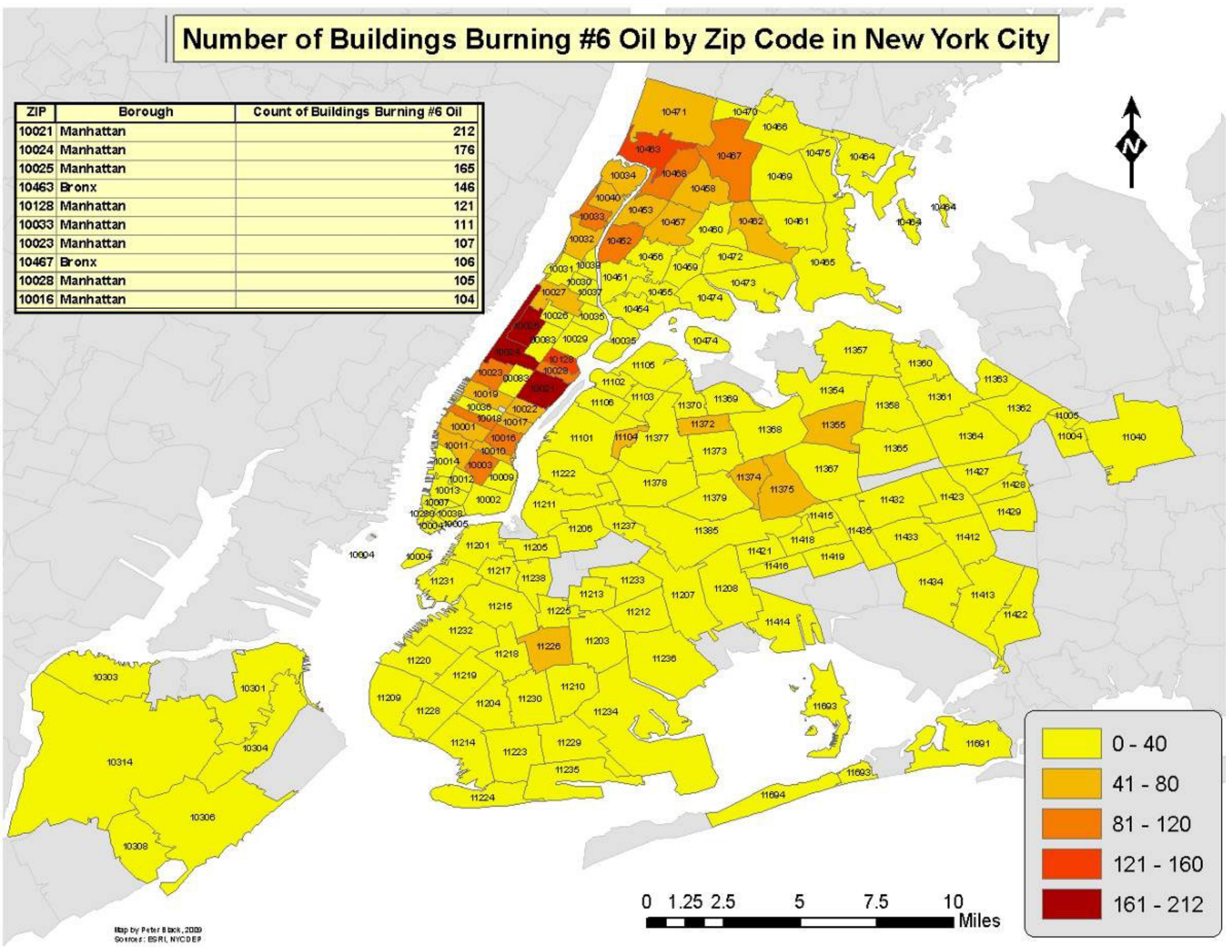
As figure 3 below depicts, almost half of the approx. 6,800 large buildings with active permits burning No. 4 or No. 6 oil are located in Manhattan.[19]

Figure 3: Distribution of the approximately 7,000 buildings burning No. 4 or 6 oil with active permits (an additional 2,000 buildings have permits “under review” meaning buildings trying to renew their permits or buildings that previously didn’t burn No. 4 or 6 oil applying for a permit to burn No. 4 or 6 oil.



Citywide, about 5,500 large boilers burn approximately 227 million gallons of No. 6 oil annually.[20] An additional 3,500 large boilers burn about 84 million gallons of only slightly cleaner No. 4 oil.[21] In comparison, about 700 million gallons of much cleaner No. 2 heating oil are burned annually in New York City.[22] This shows that about 27% of the total heating oil burned in New York City is dirty oil (No. 4 and 6 oil) and about 73% of heating oil burned is No. 2 heating oil.[23] Close to 9,000 buildings burn No. 4 or 6 oil while more than 25,000 large and midsize buildings burn No. 2 heating oil.[24] Thousands of smaller, two-family and single-family homes also burn No. 2 heating oil.[25] As a result, one percent of buildings, of the city's 900,000 buildings, are responsible for 86%[26] of the heating oil soot pollution and airborne nickel levels that are nine times higher than average levels of other U.S. cities levels.[27]

Figure 4: Top ten zip codes with most buildings burning No. 6 oil

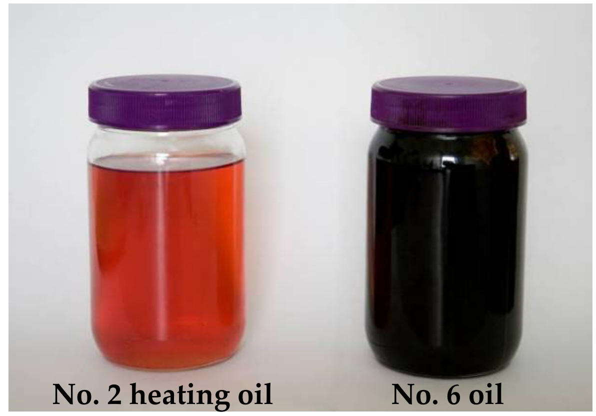


New York State relies heavily on dirty No. 4 and 6 oil for heating

The combustion of No. 4 and 6 oil in boilers is much more prevalent in New York State (most of it is burned in New York City) than in other states. In 2007, in New York State

350 million gallons of No. 6 oil were burned for heating purposes of which 227 million were burned in New York City. In comparison, these states[28] burned the following amounts of No. 6 oil for heating purposes in 2007:

- Massachusetts: 33 million gallons;
- New Hampshire: 17 million gallons;
- Maine: 16 million gallons;
- Pennsylvania: 15 million gallons
- New Jersey: 9 million gallons;
- Connecticut: 7 million gallons;
- Vermont: 3 million gallons;
- Michigan: zero gallons;
- Illinois: zero gallons;
- Colorado: zero gallons.[29]



The solutions

The good news is that pollution from residual oil can be cut by about over 93% by switching to No. 2 heating oil or natural gas. Also, implementing best maintenance practices and efficiency measures help buildings save money and pay for themselves.

The city needs to pursue a two-track strategy to achieve maximum air quality and public health benefits.

First, the city should put an immediate moratorium on new No. 4 and 6 permits for buildings that are currently burning No. 2 heating oil or newly constructed buildings that wish to use No. 4 or No. 6 oil.

Second, the Environmental Defense Fund urges the city to promulgate a new rule that will fully phase out renewal permits for No. 4 and 6 boilers by 2020. Every three years, buildings have to get their boiler permits renewed by the DEP, offering an opportunity to the city to get these buildings switched over to cleaner heating fuels over a timeframe of about six years for buildings that are not low income buildings[30] and give low income buildings until 2020 to switch to cleaner fuel. See Policy Recommendations for more details.

The city should work with the natural gas providers to speed up natural gas infrastructure for city-managed financial assistance buildings and low income buildings (natural gas prices are predicted to be cheaper than No. 6 oil) and/or help these buildings with efficiency measures.

Third, as detailed below, privately-owned buildings can switch to a cleaner fuel (like natural gas or No. 2 heating oil) and implement a wide range of good maintenance and efficiency measures that can yield some cost-effective fuel use reductions from almost any current system.

By switching from dirty residual fuel to No. 2 heating oil or natural gas, building managers can reduce boiler emissions substantially and lower their maintenance and operational costs. Similarly, regular boiler maintenance, fine-tuning of the heating system, pipe and boiler insulation and implementing efficiency upgrades on existing boilers will decrease fuel use and save money.

For example, the reduction in annual PM emissions from switching from No. 6 oil to natural gas in just one 200-unit apartment building would be the equivalent of taking more than 45 delivery trucks off the road .[31,32] Thus, the air quality and public health benefits of such reductions in pollution cannot be taken lightly.

About 420 public schools, a few hospitals and some other city-owned buildings burn No. 4 or 6 oil. No New York City Housing Authority (NYCHA) buildings are burning No. 4 or 6 oil, but a few buildings that are managed by the New York City Department of Housing and Preservation and Development (HPD) are burning the dirty fuel. Thirty Mitchell-Lama buildings citywide are also burning No. 4 or 6 oil.[33] Many of these buildings are being switched over already. EDF urges the city to devise a phase-out schedule for its remaining buildings to convert to cleaner fuels.

What can I do?

Contact your building's management and check on the interactive map at www.edf.org/dirtybuildings if your building is burning No. 4 or 6 oil. The map is also a useful tool to determine which neighboring buildings are burning dirty fuel and might be interested in splitting the costs of bringing the gas line to the buildings.[34] The New York City Department of Buildings' web site has an updated database with the type of fuel a building is burning—go to http://www.nyc.gov/html/dob/html/home/home.shtml and enter the address on the right side under BIS database, then click on "DEP Boiler Information."[35] If your building is burning No. 4 or No. 6 oil, we recommend that you provide the building's management or board of managers with the "Building owner/managing agent letter" and the "FAQ" sheet that can be found on www.edf.org/dirtybuildings which will show them how the building can switch to cleaner No. 2 heating oil or natural gas. You should also encourage your building management to do an energy audit and look into various efficiency measures presented in the chart at the end of this summary

NYC heating fuels in terms of air pollution	
No. 6 Residual Oil	Dirtiest
No. 4 Heavy-Distillate Oil (mixture of No. 2 and No. 6 oil)	Slightly cleaner than No. 6 oil
No. 2 Distillate Oil (No. 2 Heating Oil)	Cleaner than No. 4 or 6
Natural Gas	Cleanest

(or in chapters 5 and 6 of the online report). Cleaner fuels and a more efficient heating system can save buildings money and clear the air.

If your building is burning No. 4 or 6 oil, the different options for switching to a cleaner fuel are listed below. Ideally, these should be combined with regular heating system maintenance and efficiency measures to reduce fuel consumption and save money.

1. Switch to No. 2 heating oil. This switch could happen within months. Later, natural gas could be added to go to dual fuel as discussed next.
2. Switch to dual fuel, with natural gas as your primary fuel and No. 2 heating oil as a backup fuel. With dual fuel, the cheaper, "interruptible" gas rate applies. Contact your utility company regarding switching to natural gas.[36]
3. Switch to natural gas only. With natural gas only, the "firm" (higher) gas rate applies.
4. Install a co-generation system that runs on natural gas and produces both heat and electricity for the building.

Costs and benefits of switching fuels

The cost/benefits and impacts will vary according to the measures chosen. Depending on the existing burner/boiler and depending on the fuel a building switches to, conversion costs for a building with a dual fuel burner already in place on average range between $2,000 and $50,000.[37] We recommend that building owners check with their heating system contractor on the exact costs. If your heating system contractor also sells No. 4 or 6 oil to your building, we recommend going to a different heating system contractor for advice. If a building has a burner/boiler that is more than 30 years old, the building owners should look into investing in a more efficient burner/boiler. See also chapter 4 online for conversion cost estimates and Appendix A for conversion cost case studies.

The Energy Information Administration (EIA) projects that for at least the next ten years natural gas prices will be lower than prices for No. 2, 4 and 6 oils. No. 2 heating oil prices will be about 30% higher than No. 6 oil. See figure 5 below for price predictions. Calculating the cost of switching from No. 4 or 6 oil to No. 2 oil is simple. Calculating the switch to natural gas is slightly more complicated because oil prices are by the gallon while natural gas prices are calculated in therms.

Figure 5: Comparison of heating fuels price projections (Average 2010–2020) by EIA

Fuel	Energy content	Price	
		per gallon	per million Btu
No. 2 fuel oil	140,000 Btu/gal	$2.87	$20.49
No. 4 fuel oil	145,000 Btu/gal	$2.57	$17.82
No. 6 fuel oil	150,000 Btu/gal	$2.27	$15.14
Natural gas (firm rate)	1,028 Btu/scf	NA	$10.73
Interruptible natural gas	1,028 Btu/scf	NA	$8.26

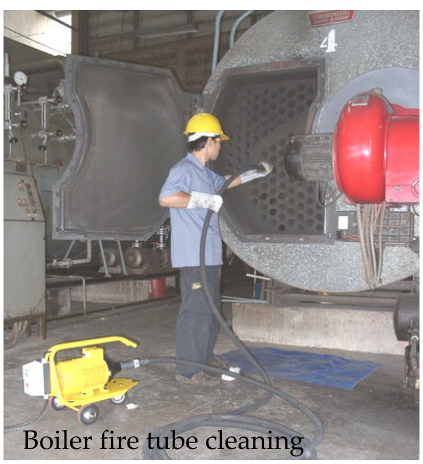
No price projections exist for interruptible natural gas rates.
Interruptible natural gas rate provided by National Grid – New York City, September 2008

No. 6 oil is about 10-30% less expensive than No. 2 heating oil, but the increased fuel costs can be mitigated or eliminated with smart management of the system to win efficiency gains (see chapter 5 online and the end of this executive summary). The price predictions show that the costs of switching from No. 6 oil to natural gas can be recouped quickly if a dual fuel burner is already in place—usually within 1–3 years (see case studies in Appendix A of the online report). This report shows how building owners can evaluate the options available to them to be part of the solution for healthy air and climate change.

The following is an example for a building that burns 50,000 gallons of No. 6 oil per year and the owner wants to switch to dual fuel natural gas/No. 2 heating oil. In June 2009, Con Edison quoted about $84,750 for natural gas heating per year with an interruptible rate.[38] In comparison, the owner would pay between $85,649 and $113,500 for No. 6 oil (price range due to different prices for No. 6 oil depending on June 2009 prices or the $2.27/gallon as per EIA's long-term predictions, see figure 5 above).

As described in chapter 4 of the online report, No. 2 heating oil and natural gas will also lead to lower maintenance and operational costs than No. 4 or 6 oil. Quantifying these lower costs is difficult, however, because they depend on the age and condition of the existing boiler (see Appendix A online for more detailed case studies). See also chapters 4 and 5 of the online report for proper maintenance practices to get heating systems running as efficiently as possible and reduce fuel use.

Proper maintenance and efficiency measures help reduce heating fuel expenses


Boiler fire tube cleaning

About 40% of the energy used to heat and cool homes is wasted.[39] Chapter 5 of the online report gives recommendations of proper system maintenance and efficiency measures.[40] As a first step, we recommend that building owners conduct a combustion efficiency test right away to ensure that the heating system is well tuned.[41] In addition, steam and hot water pipes and the boiler should be insulated wherever they are accessible without opening up walls. Regular maintenance and fine-tuning of the burner and boiler to run at maximum efficiency, in combination with proper insulation, can save thousands of dollars in reduced heating fuel use at very low cost.

As a second step, we recommend that building owners hire a specialist (for example, one recommended by NYSERDA—see Appendix E or www.getenergysmart.org/Resources/FindPartnerDetails.aspx?co=62) to perform a building energy audit to identify efficiency opportunities.[42] The chart that follows summarizes ways to reduce heating fuel consumption.[43]

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).

Policy recommendations

A new EPA study shows that the greatest health benefits (in terms of health cost savings) are achieved by reducing direct $PM_{2.5}$ emissions, such as No. 4 and 6 oil emissions.[44] To protect the health of New Yorkers and get closer to meeting federal health-based air quality standards[45], Environmental Defense Fund is urging the city to promulgate a new rule that regulates the transition to cleaner fuels in two ways. First, the use of No. 4 and 6 oil must be phased out by 2020; just as the federal government and local policies have introduced cleaner fuels into the truck, bus and construction fleets—it is time to do the same for buildings.

99 percent of New York City buildings – including single family homes -- are already using cleaner fuels (No. 2 heating oil, natural gas or ConEdison steam). Unfortunately, close to 9,000 buildings – which is 1 percent of the city's buildings -- are still allowed to burn highly polluting No. 4 and 6 oil which comes at a high cost for the air we all breathe. It is time to require that all buildings burn cleaner fuels. Given that No. 2 heating oil is readily available and given that most buildings are already burning No. 2 heating oil, the city should cease to renew boiler permits for non low-income buildings. A staggered phase-out should be implemented. EDF recommends the following phase-out schedule based on boiler age and type of burner:

- Buildings with dual fuel burners (these type of burners can readily burn cleaner fuels) already in place would need to switch fuel upon DEP boiler permit renewal (between 2010 and 2013)
- Buildings with boilers from 1980 to 2010 that burn No. 6 oil would need to switch fuel by 2014 and if they burn No. 4 oil by 2015.
- Buildings with boilers from 1979 or older that burn No. 6 oil would need to switch by 2015 and if they burn No. 4 oil by 2016.

In addition, the DEP should have discretion to allow variances until 2020 for low income buildings (term still needs to be defined for a heating oil rule).

All these steps are needed to help the city get closer to meeting federal health-based air quality standards (called National Ambient Air Quality Standards); and, to get the city closer to the goal of PlaNYC, a comprehensive sustainability plan for the city's future, which is to make New York City have the cleanest air of any big city in America.

To increase efficiency and reduce fuel costs, a DEP rule should also require annual boiler cleanings, an annual combustion efficiency test (see Chapter 5 of this report), boiler and pipe insulation and annual tuning of the burner/boiler. Multifamily residential buildings with 5 or more units, commercial and institutional buildings that operate their own boilers should be required to install a permanent stack thermometer, a makeup water meter (boiler) and a domestic hot water temperature sensor. The superintendent or the person in charge of the heating system, should be required to keep a daily log with these temperature measurements. These measurements will give the superintendent and DEP/DOB inspectors an indication on how efficiently the heating system is running and where efficiency could be increased. All these simple maintenance measures cost little and will save buildings money by reducing fuel use.

Often buildings heat the domestic hot water above 120 deg F. which is wasteful and dangerous. A DEP rule should further require that buildings do not heat the hot water above 120 deg. F.

EDF recommends that the city also takes the following steps:

- The city should issue an annual progress report listing the buildings that have switched to cleaner fuels.
- The City should work with Con Edison and National Grid to project the increase in demand for natural gas this program will produce, at the level of distribution nodes and pipes; and, work with them to ensure that delivery capacity is made available.
- In addition to the steps above, the city should work with the City Council to enact a law that requires commercial and residential landlords, co-op and condominium boards, and building owners to equip all the residents' radiators with functioning shutoff valves or thermostatic radiator valves and working steam traps. These are low-cost investments with big payoffs and increase residents' comfort.

  
  Steam trap on steel radiator

  For example, for steam systems, which are used mostly in large commercial and residential buildings, well-maintained steam traps can reduce fuel consumption by 10–20%. Also, residents should always be able to turn off their radiators so that they do not have to open windows to regulate indoor temperature.

Incentives

- The city should work with NYSERDA to create incentives for buildings (especially low income buildings) that wish to switch to No. 2 heating oil or natural gas sooner than required under a future city rule phasing out No. 4 and 6 oil.[46]
- The city should work with Con Edison and National Grid to develop incentives for buildings in close proximity to switch to natural gas as a group, with the utility companies paying to bring the gas lines to the buildings.[47] Ideally, low income buildings would receive natural gas infrastructure first.

Conclusion

Because of the significant pollution and public health impacts created by the combustion of dirty, toxic residual fuel in New York City boilers, it is imperative that the city take action now towards a full phase-out by 2020 to address this unregulated sector. At the same time that these buildings will be required to switch to cleaner fuels, the city should use this opportunity to reach out to building owners about the many opportunities they have to reduce fuel costs with proper maintenance and system upgrades that are cost-effective, save fuel and decrease pollution. Best maintenance practices and efficiency measures could also be required by rule. Black smoke and inefficient heating systems should be a thing of the past.

Chapter 1 *Why worry about boiler emissions?*

The burning of fossil fuels is the most significant source of man-made air pollution. While most people realize that automobiles and electricity production contribute to poor air quality in our cities, they may not recognize how much of the pollution in the air we breathe comes from the boilers used to heat our homes, apartments and office buildings. Residential, commercial and institutional heating systems release 50% more fine particulate matter ($PM_{2.5}$) and 17 times more SO_2 than cars and trucks[48] on New York City's roads.[49] See Figure 1. The 9,000 sludge-burning buildings in the city – which represent 1 percent of the city's buildings – contribute 87 percent[50] of the city's heating oil soot pollution.

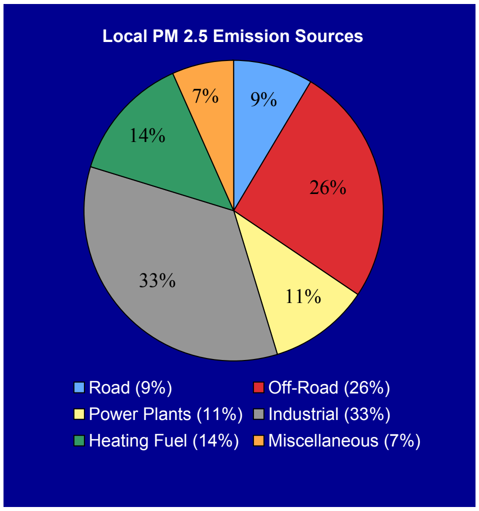


Figure 1: Data based on 2005 EPA National Emissions Inventory and Synapse Energy Economics, Inc. Report "Quantifying and Controlling Fine Particulate Matter in NYC", August 28, 2007.

According to the U.S. Environmental Protection Agency (EPA), in 2002 residential, commercial and institutional heating systems in New York City alone released more than 30,000 tons of nitrogen oxides (NO_x), over 17,000 tons of sulfur dioxide (SO_2) and over 1,100 tons of soot or fine particulate matter ($PM_{2.5}$) into the atmosphere. every year.[51] Compared to on-road motor vehicles, residential and commercial boilers emit fifty percent more $PM_{2.5}$ and seventeen times more SO_2 every year.

These emissions contribute to poor air quality in New York City and other large metropolitan areas.

National Ambient Air Quality Standards

National Ambient Air Quality Standards (NAAQS) are set by EPA and are used to define acceptable threshold levels of certain "criteria" pollutants in the air we breathe. If there is too much of one or more pollutant, the air is considered unhealthy because the pollutants can contribute to respiratory and other health problems. Many areas of the United States have air quality that does not meet the NAAQS and have received "nonattainment" designations for specific pollutants. One of several ozone and PM nonattainment areas in the United States is the New York-Northern New Jersey-Long Island-Connecticut Nonattainment Area (NY-NJ-LI-CT NAA), which includes New York City.

Black smoke coming out of chimney in NYC, Upper East Side..

The pollutants created by residential and commercial heating systems that contribute to New York City's violation of air quality standards include NO_x, volatile organic compounds (VOCs) and particulate matter less than 2.5 microns in size ($PM_{2.5}$). Emissions of SO_2 are also important because they contribute to the formation of acid rain, which damages forests and water quality throughout the Northeast.

Health effects of poor air quality

Ozone

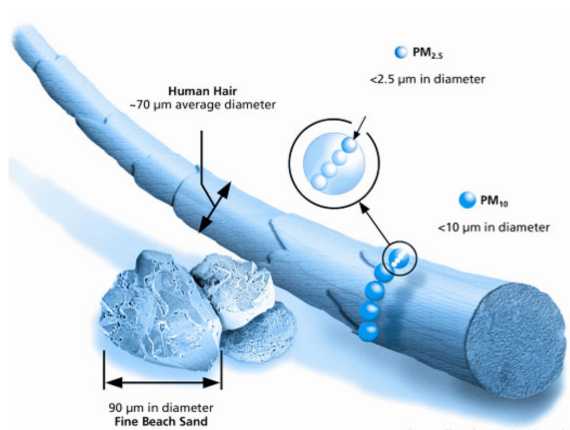
Nitrogen oxides (NO_x) are formed by the combination of nitrogen and oxygen during high temperature combustion processes such as the operation of a residential or commercial boiler.[52]

In the atmosphere, NO_x combine with VOCs to form ground-level ozone (smog) in the presence of sunlight. Ozone is an irritant that can cause breathing problems for people with respiratory diseases.

NO_x also form solid nitrate particles (secondary particulate matter) as they undergo various chemical reactions in the atmosphere.

Particulate matter (soot)

Diesel particulate matter—size compared to human hair and beach sand



Source: US EPA Office of Research & Development

Particulate matter (PM) or soot formed by combustion of fossil fuels is a complex mixture of elemental carbon (EC), unburned or partly combusted fuel such as organic carbon (OC), sulfate from fuel sulfur and lubricant products (i.e., ash and additives). PM emissions are of substantial concern because they contribute to poor visibility and negatively impact human health.

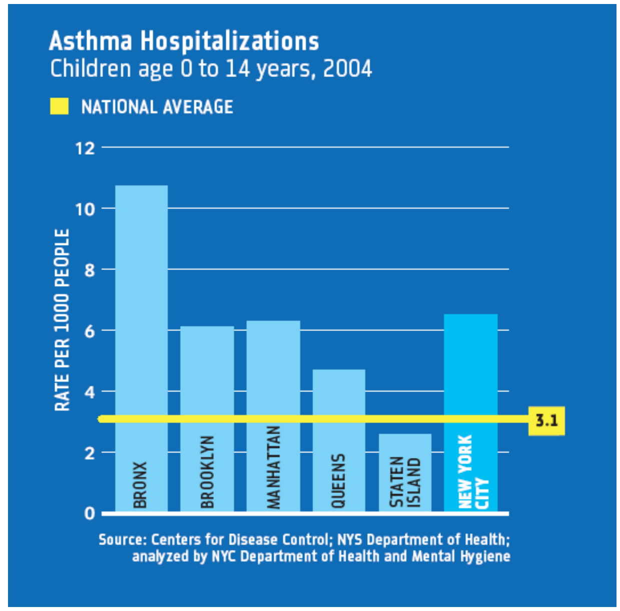
The particulate matter of greatest concern is fine and ultrafine particles with diameters of 2.5 microns or less. This portion of PM is referred to as $PM_{2.5}$. In comparison, a human hair has a diameter of approximately 70 microns—25 times greater than the diameter of a $PM_{2.5}$ particle.

When inhaled, these particles are small enough to get past the body's defenses and embed deep within the lungs. The smallest of these particles can also enter the bloodstream directly through the lungs. Human exposure to $PM_{2.5}$ can be short term (a few hours to several days), long term (from one to many years), or both.

Short-term exposure is most harmful for people with existing heart and respiratory problems, including asthma. Short-term exposure to elevated PM levels can aggravate existing lung disease, trigger asthma attacks, coughing and acute bronchitis, increase the severity of asthma attacks and may increase susceptibility to respiratory infections. Short-term PM exposure has also been linked to heart attacks and arrhythmias in people with existing heart disease.

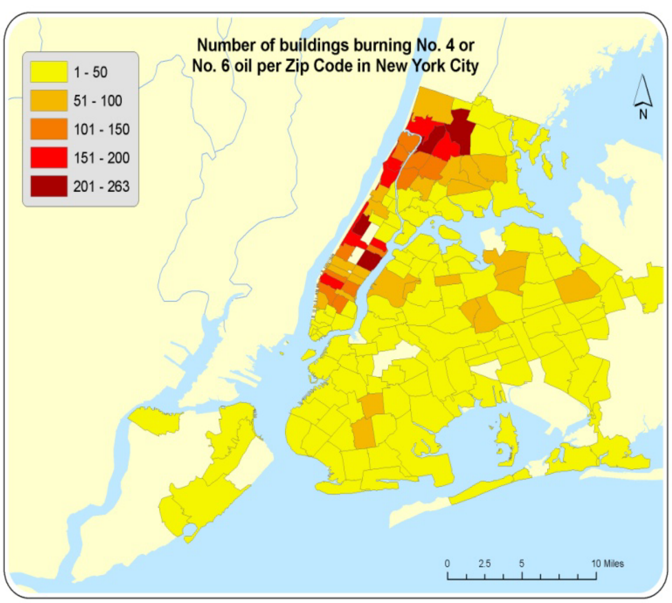
Long-term exposure to PM has been associated with reduced lung function, the development of chronic bronchitis, cardiovascular diseases[53] and even premature death. Many studies show that when particle levels are high, older adults are more likely to be hospitalized and die, often of aggravated heart or lung disease.

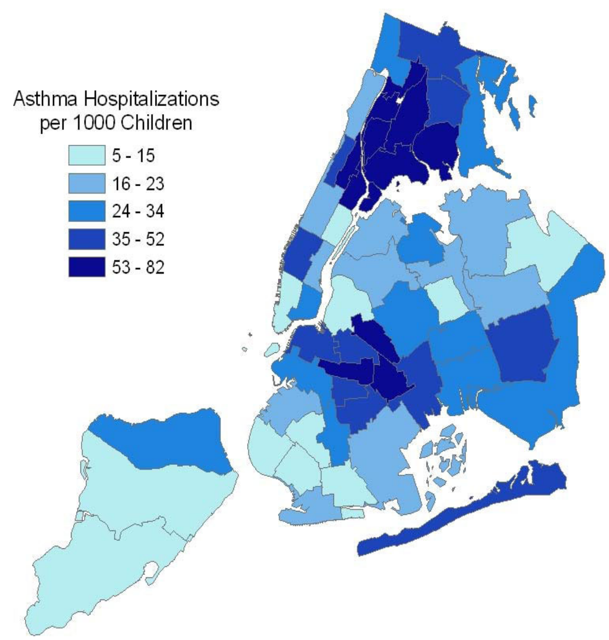
Figure 2: NYC asthma hospitalization rates compared to national average



New York City has twice the national asthma hospitalization rate among children age 0-14 years. Over 300,000 New York City children have been diagnosed with asthma. This comes at a high cost as asthma hospitalizations cost over $240 million a year. The maps below show how some of the neighborhoods with the highest asthma hospitalization rates also have many buildings burning the dirtiest heating oil (No. 4 or 6 oil) which exacerbates air quality in these neighborhoods.

Figures 3 & 4: Concentration of buildings burning No. 4 and 6 oil by ZIP codes and asthma hospitalizations per 1000 children by neighborhoods





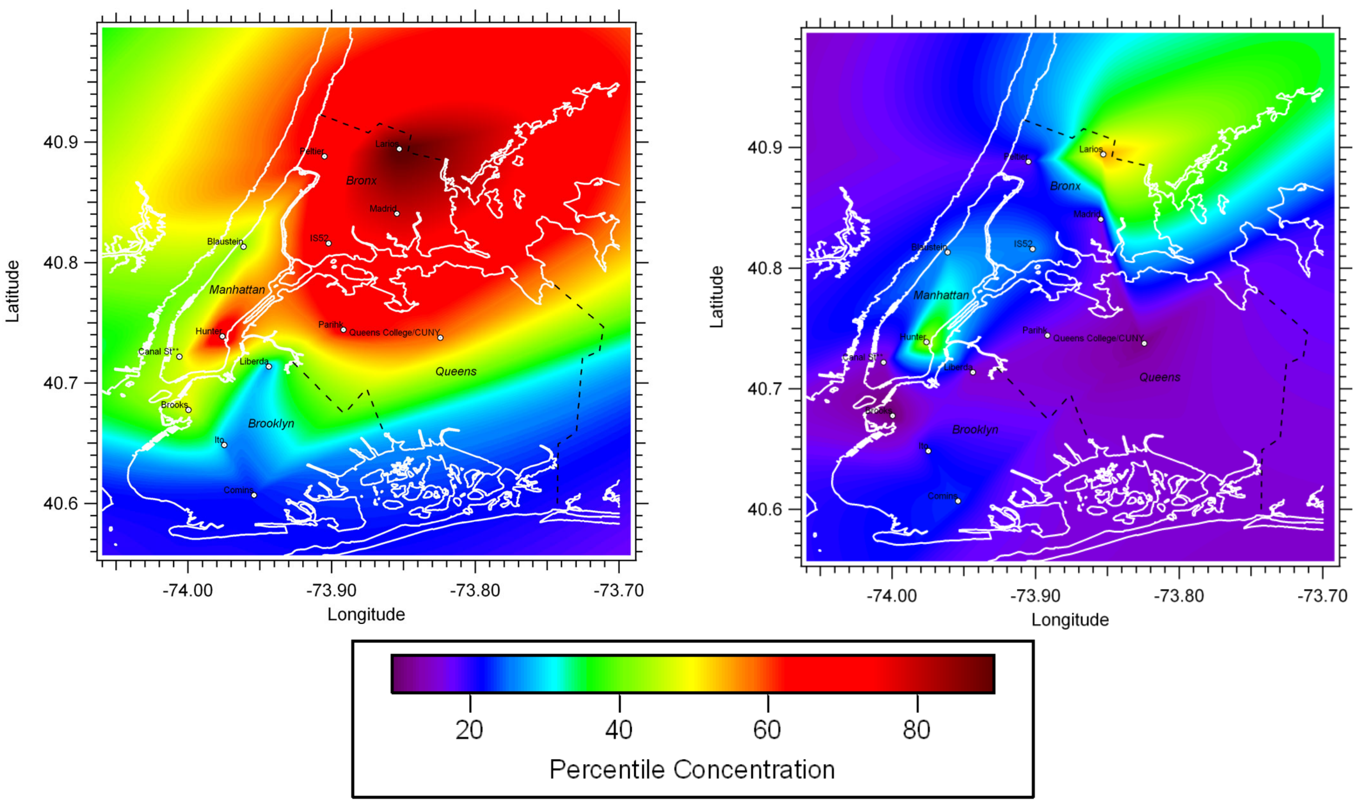
Nickel Concentration in Air Correlate with Heating Season

New York City's commercial, institutional and residential heating systems that burn dirty heating oils (No. 4 or 6 oil) also spew out heavy metals such as nickel into the air. Not surprisingly, New York City's nickel levels are on average nine times higher than average nickel levels in other U.S. cities. Nickel is a metal that when airborne has been linked to cardiovascular disease and premature death.[54] The two charts show how nickel levels in the air correlate with the heating season. [55]

A new study shows that nickel laden soot pollution is associated with respiratory symptoms in young children.[56] According to the EPA, respiratory effects have been reported in humans from inhalation exposure to nickel. Human and animal studies have reported an increased risk of lung and nasal cancers from exposure to nickel refinery dusts and nickel subsulfide. Animal studies of soluble nickel compounds (i.e., nickel carbonyl) have reported lung tumors. EPA has classified nickel refinery dust and nickel subsulfide as Group A, human carcinogens, and nickel carbonyl as a Group B2, probable human carcinogen.[57]

The charts below show the air nickel concentration (in red) in the winter and summer.

Winter *Summer*



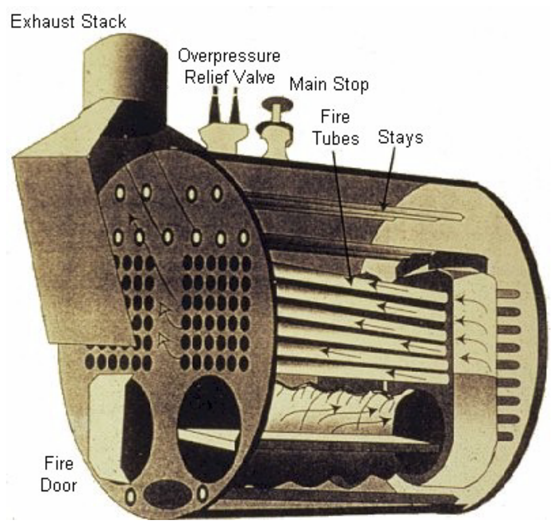
Chapter 2 Boiler 101: *typical NYC residential heating system*

One and two family homes often use forced-hot-air heating systems, which include a burner, heat exchanger and blower(s). In these types of systems, hot air is forced through ducts to every room in the house, where it blows out of vents that are usually located at floor level.

Many buildings in New York City, particularly multiunit apartments and commercial office buildings, use forced hot water or steam systems for heating. These types of systems use a boiler to heat water—the resultant hot water or steam flows through pipes to baseboard or free-standing radiators located in each room. As these radiators get hot, they radiate heat into the room.

NYC Dept. of Environmental Protection issues certificates for boilers that are rated over 2.8 million BTU/hr, and issues registrations for boilers that are rated between 350,000 BTU/hr and 2.8 million BTU/hour. These figures exclude very large sources (power plants) and small sources (individual homes). DEP does not exercise regulatory authority over power plants, which are regulated by state and federal Title V permits with emission controls. DEP's regulations also exclude fuel burning equipment in one or two family homes, or equipment with a gross input of 350,000 BTU/hr. or less; boilers meeting these exemptions will use No. 2 heating oil or natural gas.

What is a boiler?

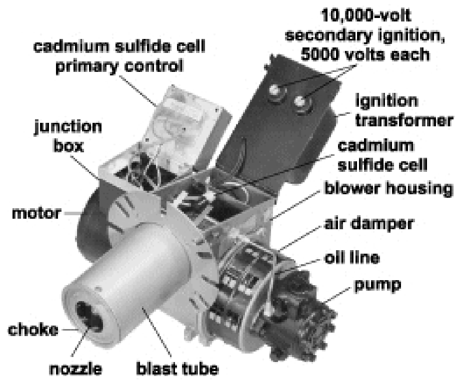


A boiler is an enclosed vessel in which water is heated and/or boiled—the water is circulated from the boiler as hot water or steam for heating or power.[58] There are two types of boilers used for residential and commercial heating systems: hot water and steam boilers. Both types are used in conjunction with baseboard heaters or radiators to transfer the heat throughout a building. They can be fired using fuel oil or natural gas.

A hot water boiler consists of a fuel burner(s), an ignition source, a blower fan, a refractory liner (to protect the floor of the boiler and building), a heat exchanger, a circulating pump, an expansion tank and at least one radiator.

A steam boiler consists of a burner(s), an ignition source, a blower fan, a refractory liner, a heat exchanger, a boiler water regulator, a condensate return pump and at least one radiator (with a steam control valve).

Oil-fired burner



Source: American Burner Corp.

How a boiler works

A heating system is controlled by a thermostat, regardless of the fuel burned or whether it produces hot water or steam. The thermostat measures the temperature within the room(s) to be heated. If the temperature falls below a preset limit, the thermostat signals the heating system to provide additional heat[59].

In a hot water system, the water in the boiler is kept at approximately 180°F at all times during the heating season. When the room thermostat calls for more heat, the circulating pump turns on, circulating the hot boiler water to the radiators in the room(s). As heat is removed from the water by the radiators, its temperature falls and the burner turns on to bring it back up to 180°F in the boiler.

In a hot water system, the burner cycles on and off to keep the water in the boiler at the right temperature, while the circulating pump cycles on and off to provide heat to the rooms.

Residential hot water boiler—gas fired

Source: Firstech Services

In a steam system, the boiler water is also kept at approximately 180°F most of the time—below the temperature required to produce steam. When the room thermostat signals that more heat is needed, the burner turns on, increasing the temperature of the boiler water above 212°F and producing steam. This steam rises throughout the building to the room radiators.

A steam system does not have a circulating pump and the burner can cycle on and off either to keep the idling boiler at approximately 180°F, or to increase boiler temperature to produce steam needed to heat the rooms.

Hot water boiler

If the temperature of the boiler water falls below 180°F, a hot water boiler's controller will initiate combustion. In an oil-burning boiler this is accomplished by a fuel pump drawing the liquid fuel from the storage tank through a filter and pumping it into the burner assembly located in the combustion chamber.

The burner assembly atomizes the fuel into a fine mist, which mixes with forced air from a blower fan, while the ignition system creates a spark. This spark ignites the fuel-air mixture (this is called light off). Once lit, the flame is stable but the ignition system continues to spark to ensure continuous combustion.

Large natural gas burner

Source: Arco Fluid

This flame is directed, using refractory bricks, toward the heat exchanger and swirl inducers. After flowing through the heat exchanger, the combustion exhaust gases are directed to an exhaust stack (chimney), which typically exits the building at roof level.

The heat exchanger consists of a series of connected metal tubes that hold the water to be heated. It also includes a circulating pump that moves the water through the system. As the flame and exhaust gases pass over the tubes of the heat exchanger, the water inside absorbs heat. The hot water is pumped to the baseboard heaters/radiators to release its stored heat before returning to the heat exchanger to repeat the process. This is called the boiler water loop, since it is a circular system.

For a natural gas-fired hot water boiler, almost all of the components are the same except for the equipment used to supply fuel to the burner (the gas train). A natural gas-fired heater does not include a fuel pump because the natural gas fuel is not a liquid. Instead it includes a connection to the utility gas supply and a valve/pressure regulator to control the flow of pressurized gas from the utility connection into the burner. The burner configuration is also somewhat different than in an oil-fired boiler because the fuel does not need to be atomized before mixing with air.

Steam boiler

Steam boilers operate much like hot water boilers, except that initiation of combustion is controlled by either the boiler water thermostat or the room or outdoor air thermostat (see discussion above). Steam boilers can burn either liquid fuel oil or natural gas, and depending on the fuel, will contain burner assemblies as described above.

Large residential steam boiler—oil fired

Source: Firstech Services

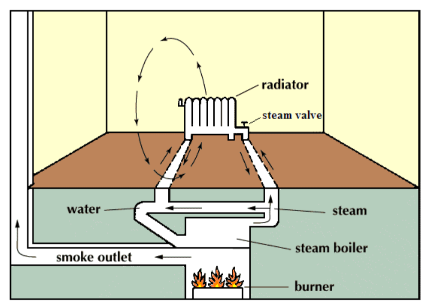
The difference between a hot water and a steam boiler is in the design of the heat exchanger/combustion chamber. In a steam boiler, the heat exchanger pipes surround the combustion chamber.

These heat exchanger pipes are filled with water, but there is headspace above them where steam can collect as it bubbles out of the water. This steam is lighter than air and will rise through the pipes to be distributed to the individual radiators, without the need for a circulating pump. In most buildings the radiators in each room are equipped with manual valves that are either open (on) or closed (off). When the valve is open steam enters the radiator, and when it is closed it does not. It is possible to equip individual radiators with valves that control the amount of steam going to each radiator, for more precise control of room temperature, but this is not common. After the steam has given up its stored heat energy within the radiator, it condenses back into water, which drains back to the boiler.

Boiler system efficiency

All new boilers smaller than 300,000 Btu/hr come with an efficiency rating called the annual fuel utilization efficiency rating (AFUE). Calculated using a standard methodology developed by the U.S. Department of Energy, AFUE is a measurement of the percentage of fuel input energy that will be converted to useful heat over an entire heating season. This rating was established to help consumers compare different options when purchasing a new piece of equipment or upgrading an existing system.

Residential steam system



Source: Britannica Online Encyclopedia

For example, an AFUE rating of 80% means that for every gallon of fuel burned in the boiler, 80% of the energy it contains will be transferred to the hot water or steam in the heat exchanger and be directed to the room radiators for heating the building. The remaining 20% of fuel input energy will be exhausted through the stack and will be lost. AFUE only refers to the unit's fuel efficiency, not its electrical usage.

Boilers with a higher AFUE will use less fuel to heat the same amount of space because less energy is lost through the exhaust stack.

The U.S. Department of Energy (DOE) mandated that, beginning in 1992, all newly manufactured small residential boilers must have a minimum AFUE of 80%. In comparison, many old boilers have AFUE ratings of only 55–65%.[60] Today, there are many residential natural gas furnaces and boilers that have AFUE ratings of 95% or higher.

AFUE ratings do not apply to the larger boilers used in multi-family apartment buildings and commercial buildings. These boilers are typically rated for efficiency using various non-DOE rating systems.

Hot water heat vs. steam heat

Hot water and steam heat systems each have distinct advantages and disadvantages. These characteristics can determine what type of system is best suited for a specific building. The discussion of advantages and disadvantages below assumes that either type of system is maintained and working properly.

Hot water generally provides even heat distribution throughout the building since the water is forced through the system using circulating pumps. It is also practical to create multiple zones within a building, each controlled by a separate room thermostat. Hot water systems are very quiet because there isn't any air in the system and they generally require little maintenance since there are few moving parts.

System type	Advantages	Disadvantages
Hot water heating	• Even heat distribution • Quiet operation • Low maintenance • More efficient	• Slower to deliver heat • High electricity consumption • Small reservoir of heat capacity • Less practical for very tall buildings
Steam heating	• Large reservoir of heat capacity • Low electricity consumption • Fast heat delivery	• Uneven heating • High fuel consumption • Large radiators • Noisy operation

On the other hand, hot water systems are slower to deliver heat than steam systems as they have a smaller reservoir of heat. They can have higher electricity consumption because of the power required by the circulating pumps to keep the water flowing in the water loop. Hot water systems have generally not been used for buildings higher than six floors—because of the high static water pressure developed in the system. However, their greater efficiency makes them worth while even in moderately tall buildings.

Steam systems have a large capacity to store heat since it takes a lot of energy to turn water into steam; this means that a steam system can deliver heat quickly because of the stored energy. Steam systems also have low electricity consumption because they use the natural buoyancy of steam to deliver it throughout the building and don't require electrically driven circulating pumps. Steam systems can be used in multistory buildings.

Steam systems, however, can often produce uneven heating throughout the building since there isn't a pump to force the heat to the radiators. Also, the radiators generally must be larger than those used in a hot water system, to help extract as much heat as possible from the steam. It is more difficult to create multiple heating zones in a building heated with steam than it is in one heated with hot water.

Steam systems can be noisy because of a condition known as "steam-hammer," in which water condenses in a horizontal section of pipe and cannot drain back to the boiler. When the system is subsequently turned on again, this water can be picked up by the steam and hurled into the pipe fittings, creating a loud bang that sounds like someone hitting the pipe with a hammer.

Major boiler manufacturers

- Carrier Corporation
- Bryant Heating and Cooling
- Smith Cast Iron Boilers
- Trane Residential
- York International
- Peerless Heater Company
- Crown Boiler Company
- Weil-McLain
- Burnham

Steam systems are generally significantly less efficient than hot water systems, requiring more fuel to heat the same amount of space. This is somewhat offset by their lower electricity use.

Other building heating system components

Additional equipment is necessary for a boiler to run, including a feed water supply, a boiler loop/ heat delivery system, fuel storage and supply, and temperature control.

Feed water supply

A feed water supply is essential for boiler operation. For a hot water boiler, the inside should be completely filled with water. For a steam boiler, there should be a headspace left at the top for steam to form. Both hot water and steam boilers have the same feed water components, only the set point for the boiler water level is different. The feed water components usually include:

- Water feed valve (with level sensor)
- Pressure reducing valve
- Air purge vent
- Backflow preventer
- Water supply pump

Boiler loop/heat delivery

The boiler loop is the distribution circuit for heat delivery. The boiler loop for a hot water system is usually a closed system, meaning that all water that leaves the boiler to go to the radiators eventually returns to the boiler. This loop has a supply and a return pipe to and from the boiler. On the return side, there is a circulating pump to keep the water moving. On the supply side, there is a flow control valve and an expansion tank to allow for changes in water pressure.

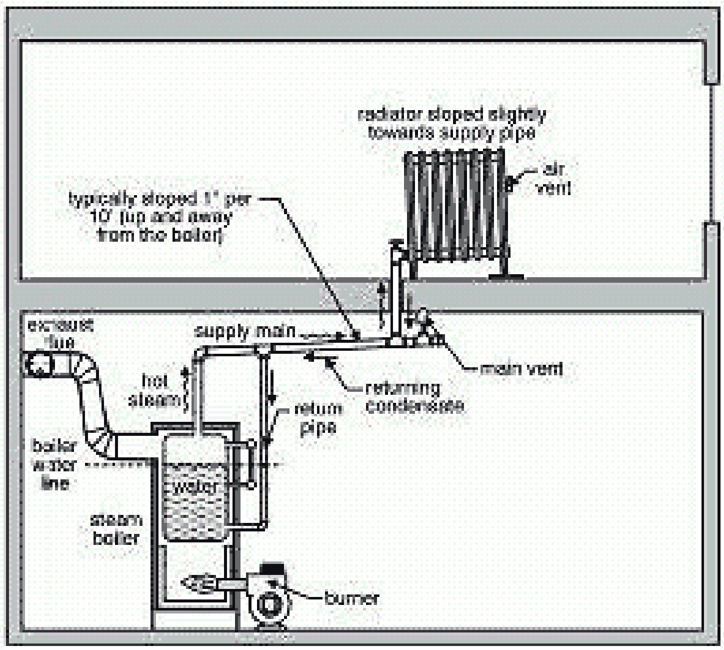
Like a hot water heating loop, a steam system is also a closed loop. This steam loop can have single pipe or double pipe arrangement.

A single pipe system uses the same pipe to supply steam and return the condensed liquid (condensate) back to the boiler. In a double pipe arrangement there is an inlet and an outlet from the radiator. This allows much more controlled, even heating, as well as improved efficiency.

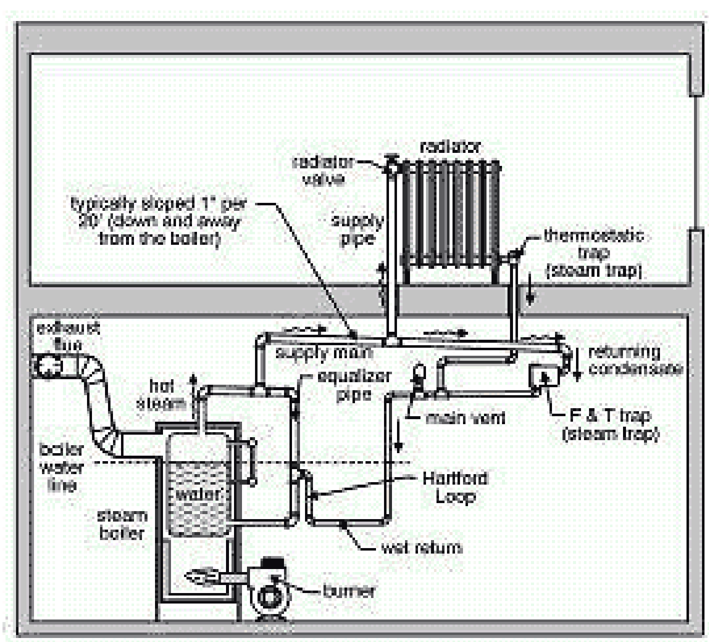
Heat delivery can be a baseboard heater (hot water), a radiator (steam or hot water), or bare pipes behind walls or under the floor (hot water). All of these designs use convection currents to release heat into the room before the hot water or condensate returns to the boiler.

Steam system designs

Single pipe system



Double pipe system



Fuel Storage and Supply

Hot water boiler steel expansion tank

Source: High Performance HVAC

For a boiler that burns fuel oil, a storage tank is necessary to hold the fuel. These tanks are usually located aboveground near the boiler, inside or outside of the building, or buried underground. Residential fuel tanks typically hold 275–330 gallons for aboveground tanks and 550–1,000 gallons for underground tanks.[61]

An oil supply system is used to transfer the fuel oil from the tank to the boiler. First, the fuel is drawn from the tank using a fuel delivery pump. Next, the pump forces the fuel through a strainer and/or filter, removing any impurities in the oil. Lastly, the fuel flows into the burner assembly for combustion.

For a boiler that burns natural gas, there is no storage tank, only supply equipment. Natural gas is supplied from a utility pipeline in the street to a meter that is usually located on the outside of the building or in the basement. The meter measures the amount of fuel used. Downstream from the meter there is usually a pressure regulator to maintain a set pressure. After the regulator and near the boiler there is a gas valve that modulates the amount of natural gas flowing to the burners. The gas valve receives instructions from the boiler control system to deliver the amount of fuel needed.[62]

Temperature control

Heating area temperature control is monitored by a thermostat. A thermostat is a thermometer attached to a set point relay, which sends a signal to the boiler.

The thermostat monitors the temperature in a target area. If the temperature falls below a preset temperature, the thermostat sends a signal to the boiler controller to initiate light off. When the target area reaches the desired temperature, the thermostat sends another signal to the boiler controller to stop firing.

As discussed previously, many steam systems in New York City are controlled by a thermostat that monitors outside air temperature rather than interior room temperature. This method of boiler control is much less efficient.

Chapter 3 The fuel effect: *What is being burned matters*

There are three types of fuel used in residential and commercial boilers for heating:

- *Residual fuel oil*
- *Distillate fuel oil*
- *Natural gas*

In general, a heating system can burn any of these fuels, regardless of whether it produces hot water or steam. Heating systems designed for each fuel type will have different fuel supply systems and burners, but the other components of the system will be the same (heat exchanger and heating supply loop— see chapter 2).

Both residual and distillate fuel oils are liquid fuels derived from petroleum. In the United States there are six grades of fuel oil, numbered 1 through 6. The lower the number, the lighter the fuel is, with lower boiling point, viscosity and energy content per gallon. No. 1 through No. 4 fuel oil grades are considered to be distillate fuels, while No. 5 and No. 6 fuel oils are considered residual fuels. No. 5 residual fuel is not burned in heating systems in New York City. No. 4 oil is a mixture (50/50mix) of No. 2 heating oil and No. 6 residual fuel. Heavy residual oils are so viscous that they are solid at room temperature and must be kept in heated storage tanks.

The distillate grades typically used in boilers include No. 2 fuel oil and No. 4 fuel oil. The residual grades used for heating system boilers include both No. 5 and No. 6 fuel oil.

Compared with residual fuels, distillate fuels are more expensive per gallon but they are much cleaner, i.e., they produce significantly lower emissions of NO_x, PM and SO_2 when burned in a boiler.

Natural gas, which is primarily composed of methane (CH_4), is a lighter than air gas that is typically supplied to buildings via underground distribution pipelines owned by a utility company.

Natural gas is the cleanest of the fuels typically used for residential and commercial space heating—when burned in a boiler it produces much lower emissions than either residual or distillate fuels do.

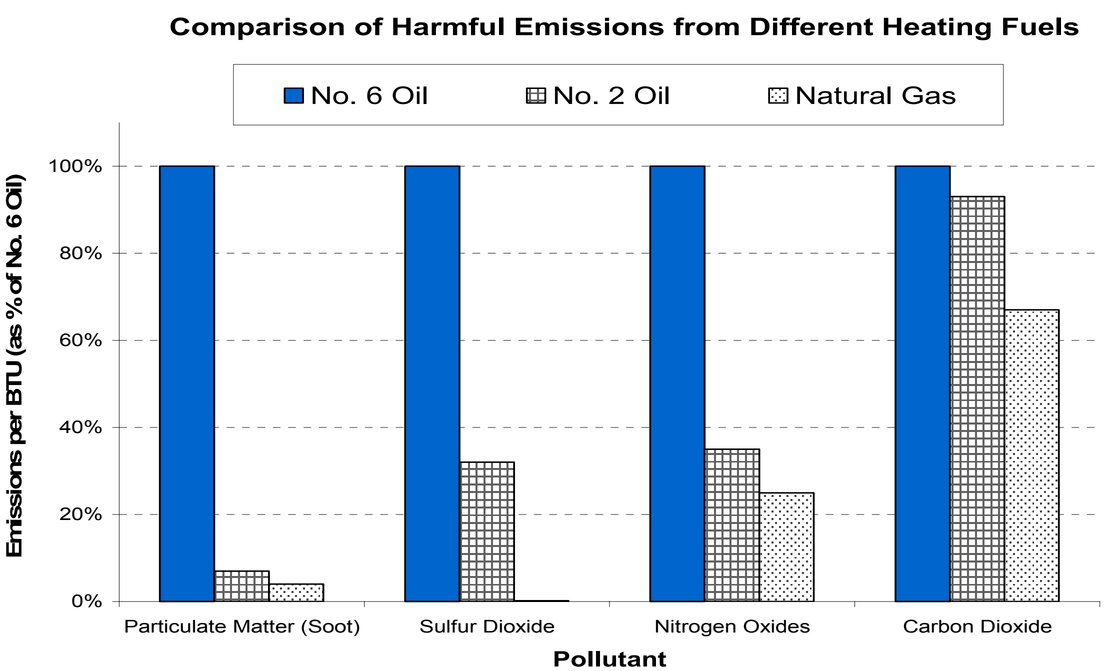
Comparison of petroleum fuel oils

Property	Distillate fuels			Residual fuels	
	No. 1	No. 2	No. 4	No. 5	No. 6
Energy content (Btu/gal)	135,000	140,000	146,000	144,500	150,000
Flash point (°F)	100	100	131	131	140
Specific gravity	0.82	0.86	0.91	0.94	0.96
Maximum Allowable Sulfur content (ppm)—NYC	2,000	2,000	3,000	3,000	3,000

Switching from No. 6 oil to No. 2 heating oil reduces $PM_{2.5}$ emissions by about 94%, SO_2 by about 68% and nitrogen oxides (NOx) by about 65%. Switching from No. 6 oil to natural gas reduces $PM_{2.5}$ emissions by about 96%, SO_2 by over 99% and NOx by about 75%. In terms of global warming pollution, switching from No. 6 oil to No. 2 heating oil reduces heat-trapping CO_2 emissions by about 7%, and natural gas reduces CO_2 emissions by about 30% compared to No. 6 oil.[63]

Figure 2 below depicts the dramatic difference in pollutants generated by No. 6 oil compared to No. 2 heating oil or natural gas. No. 4 oil is typically a 50/50 mix of No. 6 oil and No. 2 heating oil.

Figure 5:



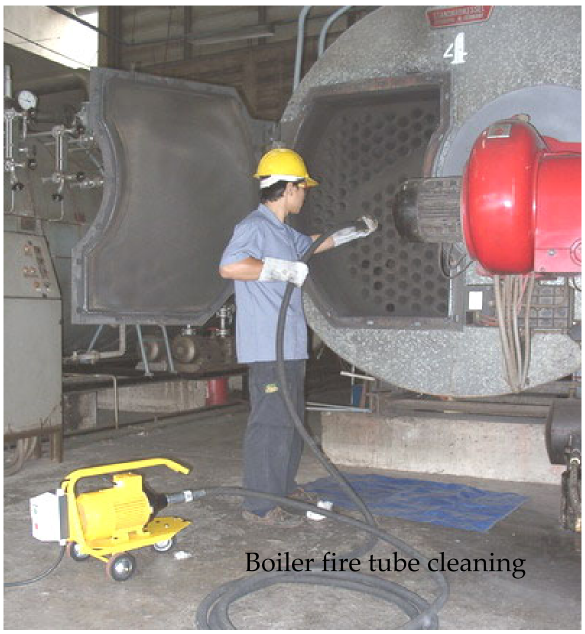
Residual fuels

Residual fuel, No. 6 oil, is the heaviest and thickest of all fuel oils—it literally comes from the "bottom of the barrel" of refined petroleum. It resembles tar or asphalt and must be stored in heated tank kept at approximately 100°F to keep it liquid so that it can be pumped into the burner of a boiler. When being pumped, the temperature must be increased to approximately 150°F to 200°F.

Residual fuels usually contain high concentrations of sulfur and other contaminants such as heavy metals. The sulfur content of residual fuel is limited to 3,000 parts per million (ppm) in New York City by local law that was later incorporated into state limits. However, in neighboring counties the sulfur limit is 10,000 ppm and in some parts of the country No. 6 oil can contain as much as 40,000 ppm sulfur.[64]

Residual fuels have higher energy content per gallon than distillate fuels—No. 6 oil contains approximately 150,000 Btu/gal.[65]

Residual fuels are less expensive per gallon and less expensive per Btu than distillate fuels. According to the Energy Information Administration, the average price of No. 6 fuel oil in 2010 for commercial customers will be $10.97 per million btu (mmBtu), which is $1.65 per gallon. Over the next ten years the average price of residual No. 6 oil is projected to increase slowly, reaching $16.68/mmBtu in 2020. Average prices for No. 6 fuel oil are projected to be approximately $15.14/mmBtu between 2010 and 2020.[66]



Boiler fire tube cleaning

Because residual fuels are very viscous and require heating for them to flow, they are generally only used in large boilers with heating capacity greater than 2.5 million Btu/hr (mmBtu/hr). The heating equipment, in addition to the energy required to keep the fuel liquid, is expensive; for smaller boilers these costs generally outweigh the fuel cost savings relative to distillate fuels.

Since No. 4 and No. 6 oil contain a high percentage of contaminants and produce greater particulate emissions when burned than No. 2 heating oil, boiler cleaning and maintenance is required frequently. During operation, soot accumulates on the surfaces of the heat exchanger and pipes, reducing the efficiency of heat transfer. This soot must be removed during the heating season by operating a soot blower.[67] If the collected soot is not removed regularly, the efficiency of the boiler will decrease and more fuel will be required to heat the building.

Distillate fuels

No. 1 through No. 4 fuel oils are considered distillate fuels. These fuels, which are liquid at room temperature, are less viscous and have lower energy content per gallon than residual fuels. They also have lower sulfur content and fewer contaminants.

No. 2 fuel oil is a medium distillate that is used in diesel engines and also as heating oil. No. 2 fuel oil usually has an energy content of 140,000 Btu/gal (7% less energy per gallon than No. 6 oil).

The sulfur content of distillate fuels used for heating is regulated at the state level and varies significantly by location. In New York City, the maximum sulfur allowed in No. 2 heating oil is 2,000 ppm.

Distillate fuels typically cost more than residual fuels. According to the Energy Information Administration, the average price of No. 2 fuel oil for commercial customers in 2010 will be $16.15/mmBtu, which is $2.26 per gallon. Over the next ten years the average price of No. 2 oil is projected to increase slowly, reaching $22.11/mmBtu in 2020. Average prices for No. 2 fuel oil are projected to be approximately $20.49/mmBtu between 2010 and 2020.[68]

Northeastern states' heating fuel sulfur limits

State	Sulfur Limit In percent	Sulfur Limit In parts per million
Connecticut	0.3	3000
Maine	0.3 to 0.5	3000 to 5000
Massachusetts	0.3	3000
New Hampshire	0.4	4000
New Jersey	0.2 to 0.3	2000 to 3000
New York Upstate	1.0 to 1.5	10,000 to 15,000
New York Downstate	0.2 to 0.37	2000 to 3700
Rhode Island	0.5	5000
Vermont	2.0	20,000

Source: NESCAUM, 2003

When burning No. 2 heating oil there is significantly less boiler maintenance required than when burning residual fuel. Distillate fuels do not need to be heated, nor do they require soot blowers. This reduces the maintenance load to quarterly or biannual cleaning and inspection. The maintenance cost savings relative to residual fuels at least partially offsets the increased fuel cost of distillate fuels.

Comparison of heating fuels price projections (Average 2010 - 2020)

Fuel	Energy content	Price	
		per gallon	per million Btu
No. 2 fuel oil	140,000 Btu/gal	$2.87	$20.49
No. 4 fuel oil	145,000 Btu/gal	$2.57	$17.82
No. 6 fuel oil	150,000 Btu/gal	$2.27	$15.14
Natural gas	1,028 Btu/scf	NA	$10.73
Interruptible natural gas	1,028 Btu/scf	NA	$8.26

No price projections exist for interruptible natural gas rates.
Interruptible natural gas rate provided by National Grid – New York City, September 2008

The heaviest of the distillate fuels is No. 4 oil. No. 4 oil is usually made by splash mixing residual No. 6 oil with No. 2 heating fuel in a 50/50 mix, and has a heating value of approximately 146,000 Btu/gal. No. 4 oil is normally used in industrial and commercial boilers, as well as in marine vessels.

Because No. 4 distillate is made using residual and distillate fuels, it possesses some qualities of both fuel types. Like No. 2 oil, No. 4 oil is a liquid at room temperature and does not have to be stored in a heated tank. In order to improve fuel atomization, however, it generally must be heated (using a heat exchanger in the supply line) prior to being pumped into the boiler's burner assembly.

No. 4 oil has higher energy content than No. 2 oil, and is typically priced mid-way between the cost of No. 2 oil and No. 6 oil. Based on Energy Information Administration projections, the average price of No. 4 oil between 2010 and 2020 is expected to be approximately $17.82/mmBtu ($2.57/gallon).[69]

It is worth mentioning that the Mid-Atlantic/Northeast Visibility Union (MANE-VU) has formed a regional coalition of state governments from Maine to Maryland and the oil industry to improve air quality and visibility in the region. MANE-VU's plan is to lower the sulfur content of heating oil to 500 ppm by 2012 and 15 ppm by 2016 for No. 2 oil and also contain a biofuel component. Due to the dramatic reduction in sulfur levels, high efficiency boilers can be installed further reducing emissions.[70] Thus, this regional strategy does not improve upon the existing limits in New York City (3000 ppm) for No. 4 and 6 oil. Another major effort of MANE-VU is to improve heating system efficiency. Go to www.nescaum.org for more information.

Biodiesel fuel

Biodiesel fuel is a distillate-type liquid fuel typically produced through the reaction of a vegetable oil or animal fat with methanol, in the presence of a catalyst, to yield glycerin and methyl esters. These methyl esters are separated from the methanol and glycerin and sold as biodiesel fuel. The methanol is reused in the production process and the glycerin is sold for other uses. The energy content and physical properties of biodiesel are similar to those of No. 2 petroleum distillate fuel, though it has virtually no sulfur and contains more fuel-bound oxygen.

Therefore, biodiesel can be used in the place of No. 2 distillate, both in boilers and in diesel engines. For diesel vehicles and boilers, biodiesel is typically used as either a B5 blend of 5% biodiesel and 95% petroleum diesel, or a B20 blend of 20% biodiesel and 80% petroleum diesel.

Emissions testings have shown that the use of B20 biodiesel in a boiler can reduce PM emissions by 20%, as well as decrease NO_x emissions by up to 20%.[71] Blends with higher biodiesel content can provide greater PM reductions. For example, the Brookhaven National Laboratory (BNL) has studied the use of bioheat blends in oil-fired heating systems for several years. BNL is the national leader in the United States for testing of fuels and heating equipment for the oilheat industry.[72] One focus of the research at BNL has been to determine if bioheat blends could be substituted for conventional heating oil without modification or adjustment to existing oil-fired heating systems.[73]

The results have shown that nearly identical, and even somewhat improved, combustion performance can be achieved with bioheat blends of up to approximately 30 percent concentration without any changes. Another result that was seen often in laboratory tests was that the addition of biodiesel to heating oil led to a reduction in the emission of nitrogen oxides (NOx) from the heating systems. The $PM_{2.5}$ testing showed that particulate emissions were directly and primarily dependent on the sulfur content of the fuel. Initial laboratory testing data has indicated decreasing $PM_{2.5}$ emissions with increasing biodiesel concentrations in the bioheat blends. Because biodiesel contains little or no sulfur, increased use of bioheat blends should therefore be expected to contribute to reduced smog in major urban areas.[74]

Quality control is of critical importance during biodiesel production and distribution. The National Biodiesel Board has established the BQ-9000 quality control program for biodiesel manufacturers. Under the BQ-9000 quality control program, all production batches of biodiesel must be tested for compliance with the ASTM D 6751 standard. All biodiesel deliveries to wholesale distributors must be tracked to enable tracing of downstream problems back through the supply chain to the original producer.[75]

The main benefits of using domestically produced biodiesel fuel in either a diesel engine or a boiler is reduced emissions, reduced use of imported petroleum fuel and domestic job creation if U.S. soybeans or waste vegetable oil are used as a feedstock. As a renewable fuel, the use of biodiesel also reduces net fuel cycle heat-trapping carbon dioxide emissions compared with the use of petroleum fuels. The magnitude of the reductions depends on the biodiesel feed stock. Carbon dioxide is the primary greenhouse gas produced by human activity; reducing carbon dioxide emissions through the use of biodiesel will help to slow or reduce global warming.

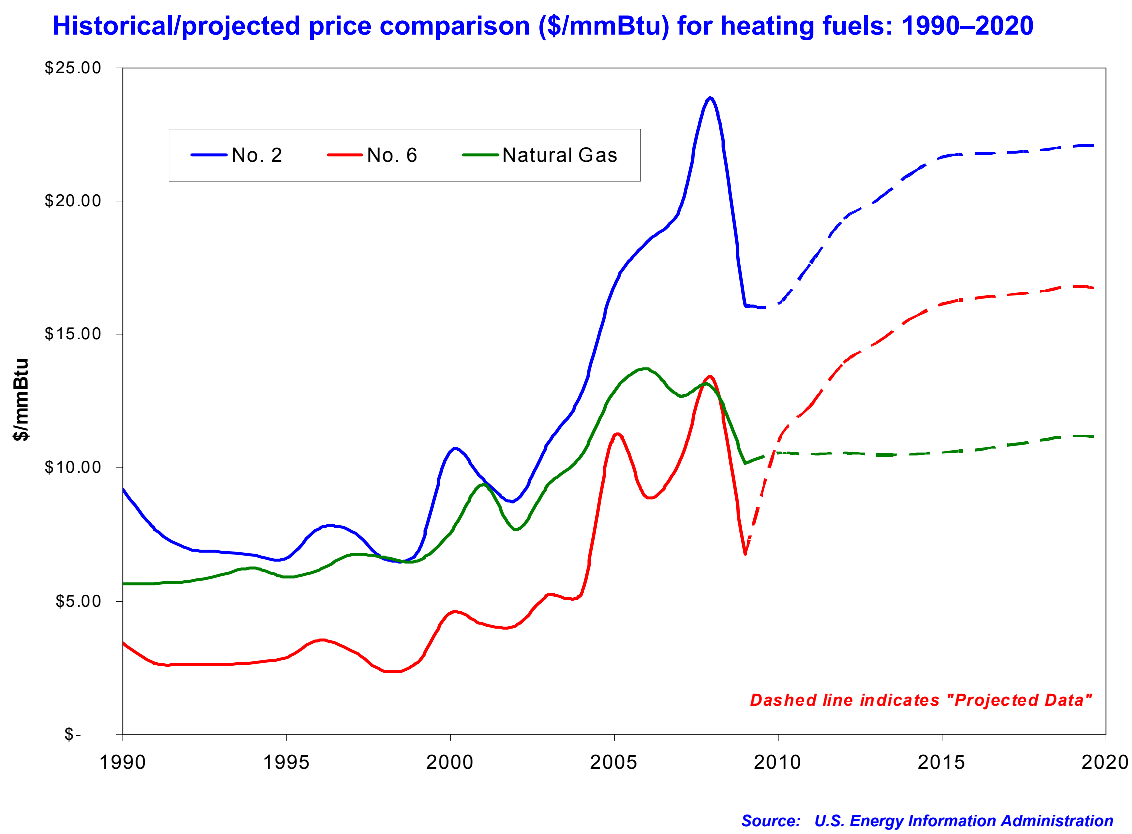
Natural gas

Natural gas is a gaseous fossil fuel primarily composed of methane, but it also includes small amounts of carbon dioxide, nitrogen, helium and hydrogen sulfide. In nature natural gas is odorless and colorless, but to aid in the detection of leaks a strong-smelling sulfur-based chemical called mercaptan is typically added to pipeline gas.[76]

In the United States, natural gas is measured in units of standard cubic feet (scf) or "therms."[77] One therm of natural gas is equal to 100 scf.

One scf of natural gas contains approximately 1,028 Btu of energy; 146 scf of natural gas would have the same amount of energy as one gallon of No. 6 fuel oil, while 136 scf of natural gas would have the same amount of energy as one gallon of No. 2 fuel oil.

According to the Energy Information Administration, the average price of natural gas for commercial customers in 2010 will be $10.55/mmBtu ($1.08/therm). Over the next ten years the average price of natural gas is projected to increase only slightly, reaching $11.13/mmBtu in 2020. Average prices for natural gas are projected to be approximately $10.73/mmBtu between 2010 and 2020.[78]



Pollution Savings When Switching To Cleaner Fuels (Source: City of New York):

Pollutant and unit	**All No. 4/6 heating fuel replaced by natural gas**	**All No. 4/6 heating fuel replaced by No. 2**
PM (tons per year)	1,282	814
NOx (tons per year)	4,839	3,794
CO2 (MMT per year)	1.01	0.13

Equivalent Pollution Reductions (Source City of New York):

Equivalent PM Reductions	- 7.4-11.6 *billion* less VMT for cars (1994-2003 MY) - 1.9-3.0 *billion* less VMT for trucks (just considering PM10, for 1999-2002 MY)
Equivalent NOx Reductions	- 5.7-7.3 *billion* less VMT for cars (1994-2003 MY) - 186-237 *million* less VMT for trucks (1999-2002 MY)
CO_2 Reductions	- 6% of the PlaNYC greenhouse gas reduction wedge for efficient buildings (16.4 MMT) every year

Over the next ten years the price of natural gas is forecast to be significantly lower than the price of either No 2 oil or No. 6 oil. Using the forecasted prices, a quantity of natural gas with the same energy content as one gallon of No. 6 oil (146 scf) would cost on average $1.61 – $0.66 less than a gallon of No. 6 oil. A quantity of natural gas with the same energy content as one gallon of No. 2 oil (136 scf) would cost $1.50 – $1.36 less than a gallon of No. 2 fuel.

However, to ensure proper supply so that interruptible service customers are not forced to switch to oil regularly, the City should work with Con Edison and National Grid to project the increase in demand for natural gas if the city bans No. 4 and 6 oils. The City should work with ConEdison and National Grid to ensure sufficient distribution nodes and pipes; and, to ensure that delivery capacity is made available.

Boiler maintenance when burning natural gas is significantly reduced compared with burning fuel oils. For residential homes, a natural gas boiler requires virtually no cleaning because natural gas does not produce significant amounts of soot that can collect on the burner or heat exchanger. Other benefits of natural gas for heating (if only natural gas is burned) include:

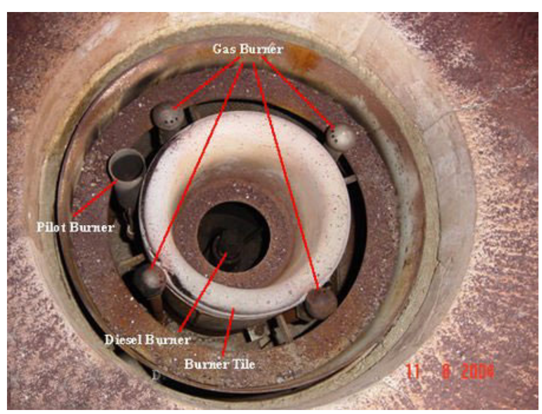
- A storage tank is not required
- Constant supply with no scheduled deliveries required
- High boiler efficiency
- Lower emissions

Dual fuel

As fuel prices increase, another option is becoming more popular: dual fuel. Using a dual fuel-capable burner system gives one the option of choosing either of two different fuels depending on which is currently less expensive. For small residential units, dual fuel burners are usually set up to burn either natural gas or No. 2 fuel oil.

For large commercial units, dual fuel burners may be set up to burn either natural gas or No. 4/No. 6 oil. Dual fueling allows a building owner to operate the boiler primarily on natural gas, but with the option to switch to the other fuel if that would be more cost effective. Not only does dual fuel capability give one the option of switching based on price, it may also allow a building owner to get a discount on the natural gas service.

Small dual fuel burner (natural gas/No. 2)



Source: Wikipedia

Most natural gas providers offer an interruptible service agreement that discounts their natural gas rate, provided the customer agrees to certain terms of the contract. The terms usually require the customer to lock in a certain amount of natural gas use per year; penalties could result if less is used. Also, the utility company can require that the customer switches to oil for various reasons (e.g. when ambient temperatures are below 19 deg F.). We recommend checking the exact terms with the natural gas providers so that an informed decision can be made.

As part of the deal, the customer is often required to have on hand at least ten days of backup fuel supply at all times. As an example, in the winter of 2008/2009, ConEdison required its customers to switch to oil for just a few days. Penalties apply if the customer is required to switch to oil but fails to do so.

Heating system emissions

All of the heating fuels discussed here create pollutants when burned in a boiler, but some are much cleaner than others. Natural gas is the cleanest fuel, while residual No. 6 fuel oil is by far the dirtiest.

Burning No. 6 fuel oil creates 26 times more PM, 4 times more NO_x and 527 times more SO_2 than burning natural gas. Even No. 2 distillate fuel oil is significantly cleaner than No. 6 residual fuel. Burning No. 2 oil instead of No. 6 oil reduces PM, NO_x and SO_2 emissions by 93%, 65% and 68%, respectively.

Switching from a dirtier to a cleaner fuel can drastically reduce the emissions that the boiler releases to the atmosphere. Unlike power plants that can install stack controls to reduce emissions, buildings have no such controls and the emissions from dirty oil pollute the air we all breathe.

As shown below, annual heating-related PM, NO_x and SO_2 emissions from a typical two-

Combustion emissions from different heating fuels

Fuel	grams/million Btu				
	PM	NOx	SO2	VOC	CO
Natural Gas	0.86	41.82	0.27	2.45	17.78
#2 Oil [1]	1.32	58.33	45.99	1.81	16.19
#4 Oil [2]	12.47	62.55	140.75	0.77	15.65
#6 Oil [3]	18.05	166.33	142.43	3.86	15.10

Fuel	g/gallon [4]				
	PM	NOx	SO2	VOC	CO
Natural Gas	0.12	5.85	0.04	0.34	2.49
#2 Oil [1]	0.18	8.17	6.44	0.25	2.27
#4 Oil [2]	1.81	9.07	20.41	0.11	2.27
#6 Oil [3]	2.71	24.95	21.36	0.58	2.27

[1] *With 2,000 ppm sulfur*

[2] The PM emission factor is integrated based on EPA AP-42 emission factors for #2 fuel oil and #6 fuel oil (0.3% S).

[3] *With 3,000 ppm sulfur*

[4] *For natural gas, g/#2 Fuel Oil Equivalent gallon*

Source: EPA AP-42 emission factors

family detached house could be reduced by 34%, 28% and 99%, respectively, by switching from No. 2 oil to natural gas. Annual heating-related PM, NO_x and SO_2 emissions from a typical 200-unit apartment building could be reduced by 199 pounds, 1,286 pounds and 1,148 pounds, respectively, by switching from No. 6 oil to No. 2 oil. They could be reduced by an additional 5 pounds (PM), 197 pounds (NO_x) and 544 pounds (SO_2) if switching from No. 6 oil to natural gas. Carbon dioxide (CO_2) emissions are reduced by about 30% when switching from oil to natural gas.

For example, the reduction in annual PM emissions from switching from No. 6 oil to natural gas in a 200-unit apartment building[79] would be equivalent to taking more than 33 delivery trucks off the road.[80]

Heating system emissions: 200-unit apartment building

Building Type	Fuel Burned	Typical Annual Energy Use		Annual Emissions (lbs)		
		mmBTU	Gallons (oil) Therms (NG)	PM	NOx	SO_2
200 Unit Apartment (with a 5 MMBtu/hr boiler)	#6 Heating Oil	5,400	36,000	214.9	1,980.2	1,695.6
	#2 Heating Oil	5,400	38,571	15.7	694.4	547.6
	Natural Gas	5,400	54,000	10.3	497.9	3.2
	% Reduction (No. 6 to No. 2)			*93%*	*65%*	*68%*
	% Reduction (No. 6 to Natural Gas)			*95%*	*75%*	*100%*
	% Reduction (No. 2 to Natural Gas)			*34%*	*28%*	*99%*

Sources: US Energy Information Association and US EPA

Chapter 4 *Reduction of fuel use with proper maintenance and reduction of emissions with fuel switching*

There are three ways that a building owner could potentially reduce the air pollution produced by a building's heating system. For those buildings that currently burn No. 6 or No. 4 heating oil, the most significant reductions would come from a change to a cleaner burning fuel, such as No. 2 oil or natural gas. Even those buildings that currently burn No. 2 oil could benefit from a number of heating system upgrades. Any heating system, regardless of the fuel it burns, will work more efficiently and produce lower air emissions if properly maintained.

The cost figures cited in this chapter cover only the cost of new or modified equipment required to switch a boiler to a new fuel or to perform the specific efficiency upgrades discussed. Many in-use heating systems may suffer from deferred maintenance issues that might need to be addressed in the context of an upgrade project. The cost of any deferred maintenance items, while potentially real and significant, are not included in this discussion for two reasons: 1) they would be unique to a specific boiler or building; and 2) they are unrelated to the upgrade or fuel switch and would likely need to be addressed regardless.

Heating system maintenance

Proper boiler maintenance is very important to sustain system efficiency and to minimize harmful air emissions. A poorly maintained boiler will emit excess pollutants and will use more fuel than a properly maintained system. Regular maintenance, cleaning and tuning of the boiler will both reduce pollution and save the building owner money.

Picture showing dirty boiler fire tubes

Picture showing clean boiler fire tubes

Boilers that burn residual and heavy-distillate fuel oils (No. 6 and No. 4) have the greatest maintenance requirements, including daily soot blowing during the heating season to remove soot from the heat exchanger surfaces and quarterly or more frequent tuning of the boiler to optimize excess combustion air. This maintenance will ensure that boiler efficiency does not degrade over time.

Boilers that burn distillate (No. 2) heating oil should, at a minimum, have an annual maintenance service performed. Basic maintenance for fuel oil boilers should include:

- Burner tip and heat exchanger cleaning
- Ash and soot removal
- Flue gas analysis/carbon monoxide test
- Air intake filter replacement
- Oil filter replacement

Residential boilers that burn natural gas normally need less maintenance, with normal service required only every other year. This service should at a minimum include:

- Air intake filter replacement
- Flue gas analysis/carbon monoxide test

If regular maintenance and boiler tuning is performed, exhaust emissions and efficiency should be within manufacturer specifications. To reduce emissions even further, switching fuels will be necessary.

Fuel switching

Fuel switching is an effective way to reduce boiler emissions, particularly for those units that burn residual fuels (No. 6 oil) or heavy distillate fuel (No. 4 fuel oil). The greatest emissions benefits will come from a switch to natural gas, but a switch to No. 2 fuel oil will also provide significant reductions. Such a fuel switch will also significantly reduce required boiler maintenance. As discussed later in the chapter, reducing the maintenance and fuel heating required when burning heavy fuels (No. 4, No. 5 and No. 6) can save approximately $1,000 to $4,000 annually. Actual maintenance savings from fuel switching will depend on the fuel used, annual total fuel use, the condition of the equipment, etc. It may also be both economically and environmentally beneficial to convert to dual fuel operation.

Summary of Potential Conversion Costs

- Conversions incur no incremental costs if the conversion happens at end of the useful life of the boiler/burner (25-35 yrs. for boilers (up to 60 if maintained and overhauled) and 20 years for burners);
- $15,000-30,000 (2 men, 3 days) for basic conversion from No. 6 oil to No. 2 heating oil

    - $5,000-10,000 to remove pre-heater and electric heater, repipe;
    - $5,000-10,000 to clean tank, steam lines;
    - $5,000-10,000 for burner "set up" to burn with proper air mix (improves efficiency by 15-20%, from 65-70% burn to 85% burn);
    - Burners less than 20 yrs. old can be adjusted to burn all fuels; specs for dual fuel burners are somewhat different, cost $4,000;
- $40,000-60,000 for complete burner replacement, including electrical and filings
- Extras
    - $1,000-2,000 for low NOx burner (not available for No. 6 oil);
    - $6,000 for optional closed loop oxygen system, boosts efficiency 2-10%;
    - $50,000 for economizer (heat exchanger in flue), boosts efficiency 5%, but these are bulky and unwieldy and are vulnerable to sulfur;
- Tank removal costs can be significant but may be inevitable under LUST regulations.

Gas line extensions can be a major capital expense. Inquire with National Grid or ConEdison if they will pay for the gas line extensions. According to National Grid or ConEdison, they will pay for the line if a buildings burns natural gas only or if several buildings switch at the same time, they will also pay for the line and let the buildings go dual fuel and burn the cheaper natural gas rate (interruptible rate).

Considerations for all boilers

The average boiler/burner have an optimal useful life of about 20 years.[81] With that said, many boilers/burners are used for much longer. If the boiler/burner are older than 15 years, a comprehensive boiler/burner inspection will give insight as to the boiler/burner's expected remaining useful life. If this evaluation concludes that the boiler/burner have less than five years of life left, then a building owner should consider buying a new, more efficient boiler/burner. If the inspection determines that the boiler/burner have a long life ahead, a cost analysis should be performed to weigh the benefits of replacing versus fuel switching or upgrading.

If the boiler was installed before the 1970s, its insulation or pipes could possibly contain asbestos. A qualified inspector can sample suspect materials to verify whether asbestos is present or not so that asbestos abatement can be done according to the law. We recommend replacing such old boilers and burners for increased efficiency and less emissions.

Asbestos abatement costs vary widely and depend on individual situations; no general cost approximation can be given. If asbestos is removed from boiler or pipe insulation, new insulation will be required. Fiberglass insulation is the preferred material for pipes and costs approximately $1.35 per linear foot.[82]

Residual fuel to distillate fuel conversion

For boilers running on residual fuel, the first option that could be considered is a switch to distillate (No. 2) fuel. Switching from residual fuel oil to distillate fuel provides emissions as well as operational benefits.

Changing from residual to distillate fuel will reduce PM emissions by approximately 94%, NO_x by 65% and SO_2 by 68%. From an operational standpoint, distillate fuel does not need to be stored in a heated tank because it is much less viscous than residual fuels and remains a liquid even at temperatures below 0°F. Also, combustion of distillate fuel does not create as much ash or contaminants, so that fuel burners and combustion areas require less frequent maintenance and cleaning.

Although distillate fuel is cleaner burning and provides maintenance benefits, upgrading a residual fuel boiler to burn distillate fuel might require a capital investment. The main component required is a distillate fuel burner. Often, burners that were installed in the last 15 years already have a burner that is readily convertible to No. 2 heating oil or even natural gas so check with your heating system engineer whether a new burner is needed when switching fuel.

The cost of these burners can range from $5,500 to $8,000, depending on boiler size.[83]

If the existing residual fuel storage tank will be retained, certain steps must also be taken to ensure proper operation with distillate fuel; alternately a new tank could be installed.

Heating fuel sulfur level

Local and State law limits the sulfur content of heating fuel sold in New York City to levels lower than typically seen in other parts of the country. No. 2 distillate heating fuel sold in New York City can have no more than 2,000 ppm sulfur, while this type of fuel typically has 3,000 ppm sulfur in other locations. No. 4 and No. 6 heating fuel is limited to no more than 3,000 ppm sulfur in New York City—in other parts of the country these heavier fuels typically have 5,000 ppm sulfur or more.

Further reductions in heating fuel sulfur content will have little effect on direct PM and NO_x emissions from heating boilers, but will reduce SO_2 emissions, which will reduce the amount of indirect PM formed in the atmosphere.

The use of lower-sulfur heating oil (less than 500 ppm) would also allow the use of secondary condensing heat exchangers on oil-fired boilers. This could boost system efficiency by up to 20%, reducing fuel use and indirectly reducing emissions from equipped boilers (see below).

First, the existing tank must be properly cleaned of all residual oil. This can cost approximately $500 to $2,000 for an average size tank and costs also vary depending on the tank location.[84] Next, the fuel heating equipment that was required to heat the residual oil must be secured or removed. This equipment can include fuel immersion heaters, steam lines, heat exchangers, etc. The costs for securing/removing this equipment can vary widely, therefore no estimate is provided here.

Distillate fuel has lower energy content per gallon than residual fuel, so a greater number of gallons will be required even though the overall efficiency of the system remains the same. One gallon of No. 6 residual fuel contains 150,000 Btu of energy, while No. 2 distillate fuel contains 140,000 Btu per gallon (approximately a 7% reduction in heating potential per gallon of fuel).

This means that if a building normally burns 10,000 gallons of No. 6 residual fuel, it would burn 10,700 gallons of No. 2 distillate fuel.

No. 2 distillate fuel is also more expensive than No. 6 fuel. Over the next ten years, the average price of No. 2 heating oil is projected to be $2.87 per gallon compared to $2.27 per gallon for No. 6 oil. The switch to No. 2 from No. 6 fuel would therefore increase average annual fuel costs by approximately $8,000 for a building that currently burns 10,000 gallons of No. 6 fuel.

This increase in fuel costs would be at least partially offset by a reduction in boiler maintenance costs, through elimination of the energy costs required to keep No. 6 fuel heated year-round and by a small increase in boiler system efficiency (1–2%) because the heat exchanger surfaces would be cleaner.

The maintenance cost savings for a 5 mmBtu/hr-sized boiler could be as high as $3,000 per year, and elimination of fuel heating could save another $1,000 per year.[85] Boiler efficiency could increase by 1–2%, saving an additional $300 for every 10,000 gallons of fuel burned.

Residual fuel to natural gas/dual fuel boilers

Switching a boiler from residual fuel to a natural gas or natural gas dual fuel system is straightforward. The main component that must be modified is the fuel burner. For a dual fuel boiler, this requires that a natural gas burner ring be installed around the existing oil burner. Depending on the size of the boiler, the cost of these burner rings can range from $8,500 to $11,500.[86]

If the boiler will retain its capability to burn residual fuel (dual fuel), all of the existing oil storage and supply equipment will stay in place, but additional natural gas fueling equipment will need to be installed. If converting just to natural gas the existing oil storage and supply equipment can be disconnected and left in place, or removed.

The required fueling equipment usually includes a natural gas meter[87], regulator and a metering or flow valve. This equipment can range in cost from approximately $2,000 to $12,000[88], depending on the distance of the boiler from the utility connection and the boiler configuration. In some cases, natural gas suppliers will subsidize the cost of the equipment (in highly competitive markets) or amortize the cost over several years by adding a surcharge to the monthly fuel bill rather than requiring an up-front payment.

Another cost that must be considered is chimney relining. According to New York State Uniform Fire Prevention and Building Codes, boilers found without a chimney liner must be lined with an approved lining system to prevent the leakage of flue gases into the building.[89] Chimney lining cost approximately $1,000 for one or two family homes and can cost much more for larger buildings depending on the size of the chimney.[90]

Also, buildings will need to check with the natural gas provider whether the buildings is located in a low pressure gas area. If this is a case, the building will need to buy a natural gas booster which can cost around $25,000.

Generally, the intent of a dual fuel conversion is to use natural gas as the primary fuel, while retaining the existing residual fuel capability as a backup, in order to take advantage of a lower interruptible rate for natural gas (see chapter 3). We recommend using No. 2 heating oil as a back up fuel because it is the cleaner oil.

To illustrate the annual cost implications of dual fuel conversion, we will assume that 25% (but typically it's only a few days out of the year where a building needs to switch to oil so this is a conservative estimate) of the annual heat requirement will come from No. 2 heating oil and 75% from natural gas. For a boiler that burned 10,000 gallons of No. 6 residual oil annually prior to conversion, the post-conversion fuel use would be 2,500 gallons of No. 2 heating oil and 1,125 mmBtu of natural gas per year.[91]

If the natural gas provider offers an interruptible natural gas rate of $8.49 per 1,000 cubic feet ($8.26/mmBtu)[92], the total average annual fuel cost after conversion would be $17,982, which is $6,200 less than the cost of burning No. 6 oil exclusively. The above interruptible rate is calculated using Energy Information Administration ten-year-average projected data, and an assumed 23% savings over the standard commercial natural gas rate.

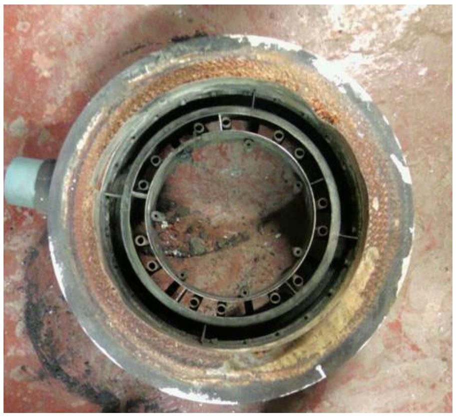
Primary use of natural gas after dual fuel conversion will reduce annual boiler maintenance and cleaning costs, for an annual cost savings of as much as $1,000 per year[93], which would further reduce total heating system operating costs. Dual fuel conversion will not significantly reduce annual costs for residual fuel heating— a sizable supply of backup residual fuel must still be kept heated year-round in case of natural gas supply interruption.[94]

These numbers are illustrative—actual annual costs will vary depending on annual fuel usage and the percentage of time using backup residual fuel.

Distillate fuel to natural gas/dual fuel boilers

The process of converting a boiler that burns distillate fuel to natural gas or dual fuel operation is similar to the process for a residual fuel boiler. The modifications required are to the burner (but check if the existing burner is already a dual fuel burner), the addition of a gas supply train and possibly a gas booster (in case of low pressure gas). Also check with an engineer and the utility company if an external extension of the gas line is necessary. If the burner needs modifications, this can usually be accomplished by adding a natural gas burner ring assembly to the existing distillate fuel burner. Prices for the required burner equipment usually range from $8,500 to $11,500[95], depending on the size of the boiler. A low pressure gas booster can cost approx. $25,000 and is a one time capital expense. As discussed above, the cost of the required gas supply equipment will generally range from $2,000 to $12,000 depending on building and boiler configuration.[96]

25 mmBtu/hr boiler gas ring



Source: Newton Wellsley Hospital

Given current fuel pricing, conversion of a distillate boiler to dual fuel natural gas operation will produce much greater annual fuel cost savings than conversion of a residual fuel boiler.

Assuming a baseline annual energy use of 1,500 mmBtu (equivalent to 10,700 gallons of No. 2 distillate fuel) and post-conversion operation with 25% oil and 75% interruptible natural gas, average annual fuel costs after conversion would be $17,000 using projected ten-year-average prices. This would be $13,700 less than the cost of operating the boiler exclusively on No. 2 distillate fuel.[97]

Primary use of natural gas after dual fuel conversion will also reduce annual boiler maintenance and cleaning costs, for an annual cost savings of as much as $1,000 per year.[98]

These numbers are illustrative—actual annual costs will vary depending on annual fuel usage and the percentage of time using backup residual fuel.

Boiler upgrade/replacement

Existing heating boilers, particularly older ones, can often be upgraded with modern technology to reduce their emissions directly and indirectly by increasing efficiency and reducing fuel use. The reduction in fuel use from efficiency improvements will also save money. Some of the more common upgrades available are discussed below.

Time delay relay (hot water boilers only)

Usually, when the thermostat calls for heat, the boiler will light off and circulate hot water to the radiators or baseboard heaters. Since boilers are insulated, they retain a significant amount of heat even if the burner has been off for some time.

A time delay relay delays burner ignition and circulates the hot water that was already in the boiler to the radiators. After a set amount of time, the boiler will fire up and increase boiler water temperature. Time delay relays usually cost about $100 and can save up to 5% in annual fuel costs.[99]

Stack O_2 closed loop control

Fuel is mixed with air in the combustion chamber of a boiler—the air provides the oxygen required for the fuel to burn. In a perfect world, only enough air would be provided to completely burn the fuel and there would be virtually no oxygen in the exhaust.

In the real world, some amount of additional or excess air is always provided to make certain that all fuel is burned inside the boiler. This ensures that both particulate and carbon monoxide emissions are as low as practical.

If too much excess air is provided to the burner, overall boiler efficiency will be reduced because the unused excess air is heated in the combustion chamber and carries energy out of the exhaust stack. Reducing burner excess air to the minimum practical level will therefore increase system efficiency and reduce fuel costs.

Many boilers operate with significantly more excess air than required because of burner/control imperfections, variations in boiler room temperature, lack of burner maintenance and changes in fuel composition. A stack O_2 closed loop control system monitors the oxygen content of the exhaust and adjusts the amount of air provided to the burner in order to maintain optimal combustion conditions with minimal excess air.

Levels of excess air possible with a well-tuned heating system

Fuel	Minimum Excess Air, %
Natural Gas	10%
#2 Oil	12%
#6 Oil	15%

Source: Energy Management Handbook

As a rule of thumb, boiler efficiency can be increased by 1% for each 15% reduction in excess air, or 40°F reduction in stack gas temperature. An annual fuel savings of up to 5% can be obtained with tighter control of excess combustion air.

Typically, only boilers 10 mmBtu/hr in size or larger can benefit from this technology. The closed loop O_2 system requires a mechanical linkage between the blower fan louvers and the burner to adjust air fuel ratio.

Smaller boilers (less than 10 mmBtu) typically use an "all-in-one" unit for their burner, blower fan, louvers and fuel pump, and the required control linkage is not feasible.

For a 10-mmBtu/hr boiler, a closed loop O_2 system will typically cost between $10,000 and $20,000.[100] A boiler of this size will typically use approximately 10,800 mmBtu of fuel annually, so that a 5% fuel savings would result in an annual fuel cost savings of approximately $8,000 (assuming No. 6 residual fuel). The payback period for installation of a closed loop O_2 system could be less than two years for this sized boiler. Larger boilers might have an even shorter payback period, depending on current efficiency.

These systems should be installed and tuned by a boiler professional, and proper training should be given to all boiler operators.

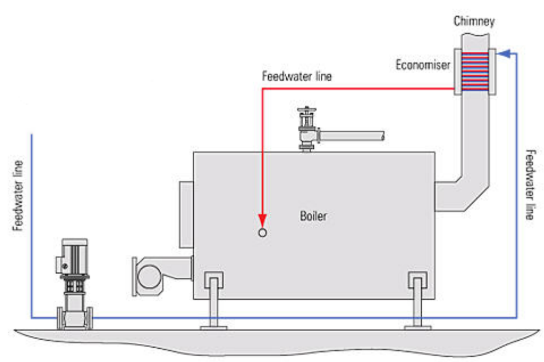
Condensing heat exchanger

Another way to increase heating system efficiency is to add a condensing heat exchanger (CHX), which is a second heat exchanger installed in the exhaust stack of the boiler. These systems are sometimes referred to as "economizers."

Combustion gases always contain water (H_2O) because the hydrogen in hydrocarbon fuels is oxidized during combustion. This water is usually in vapor form (steam) and retains significant energy—which is typically lost when the vapor exits the exhaust stack.

When using a CHX, feed water returning from the baseboard heaters/radiators to the boiler is first directed through the CHX heat exchanger in the exhaust stack. As the exhaust gases flow over the outside of the CHX heat exchanger, exhaust heat is transferred to the feed water, which then enters the boiler. Because the boiler feed water is now warmer than it would be without this recovered energy, less fuel input energy is required, thus increasing the efficiency of the boiler system.

Hot water boiler with flue gas heat exchanger (economizer)



Source: Boiler Burner Consortium

Because the CHX heat exchanger removes so much heat, the exhaust stack temperature drops below 212°F (boiling point of water), causing the water vapor in the exhaust to condense.

This condensed water must be removed—a condensate pump and drain need to be installed. Drains are usually made with PVC pipe because of its resistance to chemicals and acids.

The savings potential of a secondary CHX heat exchanger is a function of how much heat can be absorbed or recovered. A general guideline is that about 10% of boiler heat input can be recovered with a properly designed and sized CHX.

In practical terms, a CHX can only be used on boilers that burn natural gas or special low-sulfur distillate fuel. During combustion some portion of fuel-borne sulfur is converted to sulfuric acid, which collects in the condensate water of a CHX. When using fuels with sulfur content greater than approximately 500 ppm, so much acid will be present in the condensate that it will quickly corrode the heat exchanger pipes, even when made from stainless steel. In New York City, No. 2 distillate heating oil has approximately 2,000 ppm sulfur, while the sulfur content is even higher in other parts of the State and country. To utilize a secondary CHX, a distillate boiler in New York City would need to burn ultralow-sulfur diesel fuel (ULSD) instead of standard heating oil. By law, this fuel, which is used in all on-road trucks and buses, can have no more than 15 ppm sulfur. It is readily available for bulk delivery from fuel suppliers, but not necessarily from heating fuel dealers. It will likely cost more than higher-sulfur heating oil as well.

For a 10-mmBtu/hr boiler, the cost of a condensing heat exchanger is approximately $5,000 to $15,000[101], and will require professional installation.

A boiler of this size will typically use approximately 10,800 mmBtu of fuel annually, so that a 10% fuel savings would result in an annual fuel cost savings of $11,500 (assuming natural gas fuel). The payback period for installation of a CHX on a natural gas boiler could be less than one year.

Condensing Boiler for Domestic Hot Water (DHW) and Hydronic Heat.

There is now a large international market in true condensing boilers, which incorporate the condensing heat exchanger of the previous section directly into the design of the boiler. Widely used in Europe (required in some countries) and common in other parts of the US, these devices can produce domestic hot water from gas with efficiency in excess of 95% and provide hydronic space heat with efficiency ("AFUE", an official DOE test procedure) greater than 90% with properly sized radiators or fan-coil units. They are available in all sizes, from wall-hung units suitable for single-family homes to 1.5-2.5 mmBtu commercial scale units that can be arrayed to meet any practical load.

Condensing boilers are not as common as they should be in New York City. There is no doubt that this situation will change, and it is changing now, as demand for higher efficiency forces the service industry to learn the (fairly simple but different) techniques needed.

Any residential building with 100 units or more and steam heat should consider getting a gas-fired condensing boiler and storage tank to meet their DHW needs. The system will be far more efficient than the steam boiler in the summer, and depending on the fuel used in the steam boiler, may also provide less expensive hot water in heating season. Based only on summer usage, payback periods of 5-10 years are common. Optimally, if the heating system is based on oil or is dual fuel, and can provide back-up hot water, the condensing boiler can operate on interruptible gas and enjoy the lower price structure much of the year.

Proper Maintenance

The importance of proper maintenance of the boiler and distribution system to efficient operation and low emissions cannot be over-emphasized, and should be the first area to which attention and effort are applied. More often than not, the same company that is selling fuel to the building carries out the maintenance on the boiler and system. This is convenient, but it means the company has an intrinsic lack of interest in having the equipment operate at peak efficiency. If a building operator is reluctant to move to separate suppliers of maintenance and fuel, he or she should at least bring in an independent boiler firm to provide a combustion efficiency test and review other aspects of operation. Many boilers in New York City, even large ones, do not receive annual combustion efficiency tests and are operating well below their potential as a result. The NYC Dept. of Buildings requires safety inspections for carbon monoxide every year. The NYC Dept. of Environmental Protection performs combustion tests on all large NYC boilers every three years, but their goal is to ensure that emissions are within prescribed limits, and they offer no advice to owners other than "you passed".

In addition to the combustion efficiency tests, all other aspects of boiler and distribution system operation should be checked annually, including operation of all pumps and motors, steam traps, air valves, and all aspects of whatever control system is in use. It is very easy to let these items slide, since usually the heating system will continue to function, but the cost-effectiveness of proper maintenance is well established, and should be pursued before any add-ons or improvements are considered. Dan Holohan's web site, www.heatinghelp.com, is an excellent source of detailed information on best-practice techniques and solutions to common problems, and his book, "the Lost Art of Steam Heating", should be on the shelf of anyone charged with operating a large steam heating system.

Flame retention burner (oil-fired boiler only)

If a boiler has an old, inefficient burner, it may be cost effective to replace the burner with a flame retention burner. A flame retention burner blocks the flow of air up the chimney when the burner is not in use. Other advantages over a conventional burner include: reduced emissions, higher efficiency, hotter flame and more complete mixing of fuel and air. Flame retention burners usually have 5–15% higher fuel utilization efficiency over conventional burners.[102] The price for a new flame retention oil burner assembly is approximately $500–2,000 depending on boiler size, and will require a professional to install and tune.[103]

Annual cost savings for a 5-mmBtu boiler would be approximately $5,000 (assuming No. 2 oil and a 5% efficiency increase). The payback period for installing a flame retention burner would likely be less than one year.

Boiler re-rating

Many older water and steam heating systems were designed with burners that could deliver more heat than the heat exchanger could really absorb. This was done to make them more responsive to changes in demand for heat (i.e., they could heat up faster), but it is inefficient most of the time since the excess heat put out by the burner goes up the exhaust stack and is wasted.

Some older systems may be able to be "re-rated" by installing a smaller burner. In some cases, net system efficiency could be increased by 20% or more.

The current system design should be evaluated by a boiler professional prior to investing in the new burner required for a fuel conversion. This approach might also be cost effective even if staying with the same fuel, as annual fuel savings might outweigh the cost of the new, smaller burner.

Cogeneration

Also called "combined heat and power" or CHP, cogeneration has been around as long as regular generation has. It is based on the fact that burning fuel to produce electricity is limited to a conversion efficiency to electric power of 25-35%, with the remainder of the energy in the fuel being released as heat in the engine. In most large scale utility generation this heat is discarded either in cooling towers or to a convenient river, since shipping it in pipes to where it could be used is too expensive to be practical. Con Edison's steam system is an exception to this, made possible by the density of buildings in Manhattan.

Another exception is the use of small-scale generators in buildings, with the reject heat being captured and used to heat domestic hot water, eliminating the need for the gas or oil that would otherwise have been needed. If both the heat and electricity can be used, cogeneration can lower fuel bills and carbon footprints, but at the price of adding a somewhat complex piece of equipment to the building's infrastructure. There are several factors to keep in mind when considering cogeneration:

- The building must have sufficient hot water usage to make use of the reject heat. Otherwise the system will make no sense economically. Even for small cogenerators (30-50 kW), this normally means a residential building of at least 100 apartments.
- The building must be master metered for electricity. If the apartments have individual accounts with Con Edison, there will be no way to use the electrical output within the building, and Con Edison will not pay a useful amount of money for the power. Converting a building to a master meter is a good idea (more information is available at www.submeteronline.com), since it will save considerable money, but should only be done in conjunction with submeters. Simply including a fixed electricity fee in rent or maintenance payments is a terrible policy that encourages wasteful behavior.
- The building must either have an informed and enthusiastic member of its staff to manage the cogenerator, or must work with one of several companies that will install and operate the equipment as a "hands off" operation for the building.
- Since cogeneration supplies domestic hot water, a building currently using a steam boiler for heat and hot water should choose between cogeneration and a gas-fired condensing boiler as discussed earlier in this section. It would make no sense to install both.
- The decision as to whether and how to pursue cogeneration is technically complex and should only be undertaken with the advice of an expert other than the company that will install the equipment. Since the installer can charge in proportion to the scale of the equipment, there is an unfortunate tendency to oversize, resulting in poor economic performance. A program such as those offered by NYSERDA (discussed below) can provide this assessment as part of

their technical assistance, and some financial assistance may also be available, depending on how program participation is carried out.

In short, cogeneration can be an attractive option for larger multifamily buildings, but is one that should be carried out carefully and with objective, expert advice.

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.

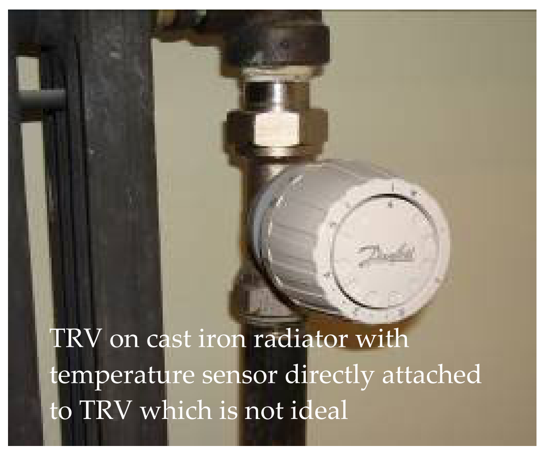
Thermostatic radiator valves and shutoff valves can bring between 3–20% fuel savings

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 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).


Weather-stripping of doors and windows

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 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

Chapter 6: *Lowering your building's electric bill*

This chapter provides a short list of measures building owners can take to reduce electricity consumption. Many investments to reduce electricity consumption have very short payback periods. To reduce electricity consumption, the following should be considered:

1. Purchase electricity generated from renewable sources from your electricity provider or switch to a provider that offers electricity made from renewable sources such as wind, solar or hydro. See, for example, http://www.sterlingplanet.com/buyConEd.php or http://www.energetix.net/.
2. For all electric appliances, electronics and light fixtures, always purchase units with the EPA Energy Star label. Go to www.energystar.gov to find energy-efficient unit models, compare efficiencies and locate dealers.
3. Change the lighting in apartments to energy-efficient lightbulbs such as compact fluorescent lightbulbs (CFLs). For more information go to www.edf.org/cflguide. Residents can be encouraged to switch to these more efficient lightbulbs by the building management even though the management typically has no control over the residents' or tenants' choice of light fixtures and bulbs. For example, a residential building can create a CFL buying service, making selected bulbs available at wholesale prices.


CFL lightbulbs

4. Add automatic lighting controls. Office buildings can be equipped with motion sensors so that the lights turn off automatically at night. For lights without motion sensors, the cleaning crew should be instructed to turn off all the lights at the end of the day.
5. Similarly, fire stairs and hallways of residential buildings can be equipped with bilevel lighting, a mechanism that keeps the lights at code-minimum levels when the space is empty but then switches to normal lighting levels when somebody enters or a door opens. See LaMar Lighting's "Occu-smart" line at www.lamarlighting.com for more information.


Bilevel lighting

6. Replace window and smaller central air conditioners (A/C) with Energy Star units
7. Replace older appliances, especially clothes washing machines, with new Energy Star models.
8. Turn off equipment that is not being used, especially A/C units, when not in use. Put power-sucking appliances like cable boxes on switchable outlet strips, or use smart outlet strips that only turn on when the appliance on one key outlet is switched on.


Programmable thermostat set at 85 deg. F while home unoccupied in the summer

9. Adjust thermostat for A/C to approximately 75–77°F to save electricity. Turn A/C off when not at home or set unit at 85°F.
10. Keep the A/C units well maintained by making sure the condenser fan is clean and by cleaning or changing the filter every three to six months.
11. Make it a company policy that employees turn off their computers at night and do not use screen savers during the workday. Have IT set up the computers to make the screens go black when not in use.

Appendix A:
Case studies of costs and savings of heating fuel conversions

All fuel prices are average projected prices between 2010 and 2020 in accordance with the Energy Information Administration Annual Energy Outlook 2009. The interruptible natural gas rate is assumed to be 23% lower than the standard commercial natural gas rate.

Case study 1: Single-family home

Fuel switch from No. 2 heating oil to natural gas

For this study, we assume that the existing boiler is a 100,000 Btu/hr boiler[117] in good working condition and does not require replacement of standard components to operate correctly.

Capital cost

Natural gas burner		$1,000
Chimney relined		$ 500
Removal of oil tank		$ 500
Natural gas piping *		$1,500
Condensate pump		$ 100
	Total	$3,600 **

Operating cost

We assume that a single-family home uses 87 mmBtu (621 gallons No. 2 fuel)[118] annually for heating. U.S. average projected prices (2010–2020) are used.

Annual No. 2 oil cost: 621 gallons x $2.87 =		$1,782
Annual natural gas cost: 87 mmBtu x $10.73/mmBtu =		$ 934
	Savings	**($ 848)**

Payback period: $3,600 / $848 = 4.25 years **

Emission savings (lbs/year): NO_x: 3.2 lbs, PM: 0.1 lbs, SO_x: 8.8 lbs.

* *Assuming no previous natural gas service.*

** *The natural gas utility may provide incentives to reduce installation costs (see chapter 6). The payback period would generally be shorter if more fuel was used annually. For 1,000 gallons of annual fuel oil use, the annual savings after switching to natural gas would be $1,350 and the payback period would be less than three years.*

Case study 2: 200-unit apartment building

Fuel switch from No. 6 residual oil to natural gas (2% efficiency increase); Add a condensing heat exchanger (10% savings)

For this study, we assume that the boiler is a 5-mmBtu/hr hot water unit in good working condition and does not require replacement of standard components to operate correctly.

Capital cost

Natural gas burner	$10,000
Chimney relined	$ 5,000
Secure oil tank	$ 3,000
Natural gas piping	$ 6,500
Condensate pumps	$ 500
Condensing heat exchanger	$10,000
Total	$35,000

Operating cost

We assume that the building currently uses 5,400 mmBtu (36,000 gallon No. 6 oil) annually for heating

Current

Annual No. 6 oil purchase: 36,000 gallons x $2.27 =	$81,720
Annual No. 6 oil tank heating (2kW heater @ 7,000kWh) =	$ 980
Annual soot blowing and maintenance	$ 3,000
	$85,700

Proposed

Annual natural gas cost: 4,900 mmBtu x $10.73/mmBtu =	$52,577
Annual No. 6 oil tank heating (2kW heater @ 7,000kWh) =	$ 0
Annual soot blowing and maintenance	$ 0
	$52,577
Savings	**($33,123)**

Payback period: $35,000/$33,123 = 1.1 years

Emission savings (tons/year)

NO_x	0.76 tons
PM	0.10 tons
SO_x	0.85 tons

Case study 3: 500-unit apartment building

Fuel switch from No. 6 residual oil to natural gas/No. 2 oil dual fuel (1% efficiency increase);Add closed-loop O_2 control (5% fuel savings)

For this study, we assume that the boiler is a 10-mmBtu/hr boiler in good working condition and does not require replacement of standard components to operate correctly.

Capital cost

Dual fuel burner	$20,000
Clean residual fuel tank	$ 3,000
Secure/remove residual fuel heating equipment	$ 2,000
Chimney relined	$ 8,000
Natural gas piping	$ 8,500
Condensate pumps	$ 1,000
Closed-loop O_2 control	$15,000
Total	$57,500

Operating cost

We assume that the building currently uses 10,800 mmBtu (72,000 gallon No. 6 oil) annually for heating

Current

Annual No. 6 oil purchase: 72,000 gallons x $2.27 =	$163,440
Annual No. 6 oil tank heating (4kW heater @ 14,000kW) =	$ 1,960
Annual soot blowing and maintenance	$ 5,000
	$170,400

Proposed

Annual No. 2 oil purchase: 18,128 gallons x $2.87 =	$ 52,027
Annual natural gas purchase: 7,614 mmBTU x $8.26/mmBTU =	$ 62,892
Annual maintenance	$ 1,000
	$115,919
Savings	**($54,481)**

Payback period $57,500 / $54,481 = 1.1 years

Emission savings (tons/year)

NO_x	1.47 tons
PM	0.20 tons
SO_x	1.56 tons

Cost and savings analysis:

Switching from No. 6 oil to No. 2 heating oil

An 86-unit building burns approximately 50,000 gallons of No. 6 oil. Two years ago, the building was equipped with a new dual fuel burner and a new boiler.

The costs of removing preheater equipment and technical changes to accommodate burning of No. 2 heating oil including cleaning of tank:

One-time expense: $8,500

Yearly additional heating costs if No. 2 heating oil costs 35 cents more than No. 6 oil plus 4% taxes (price per June 16, 2009):

Annual increase in oil costs: $18,200*

Yearly cost savings due to less maintenance costs, less electricity use and less operational costs for No. 2 heating oil:

Annual savings: approx. **($1,500)**

To offset the additional heating oil costs, building owners should consider implementing efficiency measures (proper maintenance and fine tuning of boiler system, insulating pipes as well as system upgrades) to reduce the number of gallons of oil burned. Such efficiency measures are described in chapter 5 of this report.

Potential annual savings with 10% fuel savings: **approx. ($9,000)**

An energy management system (EMS)** could reduce heating oil consumption by about 20%, which would translate into 10,000 fewer gallons burned annually. With No. 2 heating oil prices of June 16, 2009, this would reduce fuel costs annually as follows (including taxes):

Annual fuel savings: approx. **($20,000)**

* EIA predicts that No. 2 heating oil will be approximately 60 cents/gallon more expensive than No. 6 oil.

** An EMS costs approximately $20,000.

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Appendix B:
Case studies of efficiency measures

Case study: Thermostatic radiator steam traps and thermostatic steam trap replacements

This study concerns an 88-unit building on the Upper West Side, New York, NY. The heating system contractor replaced 436 thermostatic radiator steam traps (installed on the outlet of each apartment radiator) and 65 float and thermostatic steam traps (installed at the base of the steam supply risers due to low pressure riser).

The 436 thermostatic radiator steam traps and the 65 float and thermostatic steam traps cost:
$77,000

The building also replaced the vacuum return unit for:
$25,000

The building managing agent reported 30–35% less fuel consumption from the previous year.

This is a significant decrease in fuel consumption and the project will pay for itself in about five years.

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Case study: Energy management system (EMS)

An ENERGUARD™ EMS system was installed in a 322-unit building in the Bronx.

The advantage of an EMS system is that indoor room temperatures throughout the building are taken into account as opposed to old systems that only take outside ambient temperatures into account.

The ENERGUARD™ EMS system receives real-time temperature transmissions from wireless space temperature sensors that are placed throughout the building. For example, as more indoor temperature sensors report they are reading below a desired set point temperature of 72 degrees in the winter mode, the ENERGUARD™ system causes the heating plant to kick in.

The ENERGUARD™ EMS provides 24-hour temperature set point changes, thereby lowering the nighttime temperature set point in the winter time to 68 degrees or lower and raising the space temperature to 72 degrees or lower during the day. When no heating or cooling is required as determined by the outside air temperature and internal clock calendar, the heating plant is shut down.

The building's fuel consumption of No. 6 oil decreased by approximately 25% compared with previous years without the EMS system.

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Case study: Thermostatic radiator valves

A major problem with central steam and hot water (hydronic) heat is that the systems usually lack any local control. The temperature at a thermostat dips or it gets cold outside and the boiler control kicks in, sending heat throughout the building. But what if the sun is pouring in a south-facing window or wind cools one side of the building but not the other? These imbalances in load result in discomfort and overheating in parts of the building, leading to windows being opened and more fuel wasted.

What is needed is a way to turn individual radiators on and off with a shutoff valve or to regulate the amount of heat coming from the radiator in response to the temperature in that room. A device that regulates the radiator heat depending on the temperature in the room is called a thermostatic radiator valve or TRV.

When the room is above the desired temperature, the valve is closed and the radiator stays cool even if the boiler is fired by the central control. If the room temperature is below the set point, the radiator functions normally. The result is a room that stays near the desired temperature regardless of excess sunshine, wind-driven infiltration or other uneven thermal loads.

But does it save fuel and money? To answer this question, the New York State Research and Development Authority (NYSERDA) funded a study by EME Engineers. They worked with eight well-run buildings in Brooklyn, Manhattan and Bronx, all with one-pipe steam systems. (One-pipe steam is the case that is hardest to control with TRVs, so any results from this study will also hold for two-pipe steam or hydronic distribution systems.) After undertaking a set of low-cost or no-cost measures like insulating bare pipes, they recorded the fuel use for a year and began a sequenced series of installations of TRVs in five of the buildings. The other three buildings served as controls.

The results were striking and instructive. In one building that did not suffer from imbalances or overheating before the test began, the savings were negligible. The lesson: if you don’t have a problem, you will only need functioning shutoff valves and not necessarily TRVs (or maybe you don’t have a problem because every radiator already has a functioning shut off valve or a TRV).

For the other buildings, however, installing TRVs in the 50% of rooms that were most overheated resulted in savings of 3.7–12.9% (average of 9.5%) and payback periods of 1.2 to 3.6 years. For the two buildings with the greatest savings, TRVs were subsequently installed on the remaining radiators, and the overall savings jumped to 10% and 21%, respectively, with payback periods of 4.7 and 1.3 years.

The conclusion: if a building suffers from significant imbalances, TRVs offer a possible route to greater comfort that will save fuel and pay for itself in a few years.

All buildings are different, however, and you should consult with a competent heating engineer before embarking on a program to install these controls.

Manufacturers: Danfoss (www.danfoss.com/North_America/) is perhaps the most prominent manufacturer, but Macon (http://www.maconcontrols.com/) and Honeywell (customer.honeywell.com/Business/Cultures/en-US/Default.htm) also supply reliable units.

Reference: NYSERDA report 95-14, "Thermostatic Radiator Valve (TRV) Demonstration Project," 1545-EED-BES-91, September 1995, may be obtained from the National Technical Information Service at www.ntis.gov/search/index.aspx by searching for PB96-198163.

Case study: Energy management system

The value of high-quality boiler control is made clear by the savings that occurred when an energy management system (EMS) was installed in a 75-unit assisted living center on Manhattan's Upper West Side. The five-story building has about 27,000 square feet of living space and is heated by hot water circulated through radiators and convectors. The boiler is fired by gas and has a relatively modern and efficient burner.

Gas consumption by the boiler provides both hot water and space heat. Analysis of gas consumption for both a year prior to and a year after the upgrade reveals that about 10,880 therms per year were used for hot water and this usage would not be affected by the improved controller. This is a relatively small amount of fuel for hot water, less than $30 per resident per month.

Prior to the upgrade, a "reset" controller operated the boiler and controlled how much space heat was provided based on outdoor air temperature. Gas consumption for a year prior to the installation was analyzed, the hot water consumption was subtracted out and the remainder amounted to 12,840 therms consumed for heating. This indicates a building that is already efficient: when corrected for size, a typical New York City building would use 40–50% more fuel for heating.

Installing the EMS, which would typically include five temperature sensors for a building this size and a dedicated computer program to make "smart" decisions about how much heat to send up based on the data, resulted in a substantial decrease in the use of gas for heating. After subtracting out the same amount of gas for hot water usage, only 10,330 therms were used for heat. A small share of the decrease was because the second winter was slightly milder, but even after correcting for this, fuel use dropped by more than 15%.

The EMS cost about $23,000, and at a gas price of about $1.70 per therm, the savings are worth about $3,580 per year (corrected to average weather), so the EMS paid for itself in about six years. (Larger buildings would pay back more quickly.) In addition, this socially oriented nonprofit is better insulated from escalating fuel prices now and in the future and has lowered its emissions in proportion to the decrease in fuel use.

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Appendix C:

Getting in touch with Con Edison or National Grid to switch to natural gas

In order to make the switch, the building management first needs to find out whether Con Edison or National Grid is the service provider for natural gas. For Manhattan, Bronx and parts of Queens, Con Edison is the natural gas service provider. For buildings in Brooklyn, Staten Island and parts of Queens, the natural gas service provider is National Grid.

Con Edison's contact:

Go to: www.coned.com/naturalgas or call 1-800-643-1289.

National Grid contact:
Go to: http://www2.nationalgridus.com/myngrid/ or call 1-877-MyNGrid (877-696-4743)

Interruptible versus firm gas rates

There are two different price categories for natural gas: the firm rate and the interruptible rate. The *firm* rate is more expensive and applies if a building burns natural gas only. The less expensive *interruptible* gas rate applies when a building burns mostly natural gas, but for a few days out of the year switches to a backup fuel, such as No. 2 heating oil.

The firm rate is higher because the utility pays to connect a natural gas line to the building, and it requires the building to burn natural gas only as long as it takes for the utility company to recoup the costs of bringing the natural gas line to the building. Even though the rate is higher, the building operators do not need to keep oil as a backup fuel and do not run the risk of having high fines imposed.

Buildings that opt for the less expensive interruptible rate have to pay for the gas line themselves. They also need to have a dual fuel system so that they can burn the back up fuel for a few days out of the year when required by the gas company (for various reasons including outside temperatures, pricing or supply issues). High penalties apply if a building fails to switch to oil. During the 2008–2009 heating season, buildings had to switch to oil only for a few days. To be properly prepared, buildings must have at least ten days worth of oil supply on hand.

However, if a group of buildings in close vicinity all switch to natural gas, Con Edison and National Grid will pay to bring the gas line to the buildings and will also let all the buildings burn the cheaper interruptible gas rate (dual fuel with No. 2 heating oil).

To switch to natural gas, the gas service provider will need to analyze whether a building already has a natural gas line suitable to supply heating fuel and if not, how much it would cost to bring the line to the building. Once the building owner gets this information from the natural gas service provider, the building owner can make an informed decision regarding firm or interruptible gas service.

Con Edison and National Grid will most likely need the following information for converting a building to natural gas:

1. The exact address of the location in question, inclusive of zip code
2. The estimated annual consumption (oil) in gallons
3. Input (size) of boiler (typically there is a metal plate on the boiler with this information, possibly also EPA certificates with gallons per hour, which are listed on the firing gun).
4. The oil type (No. 2, 4 or 6) currently being used
5. The number of units (dwelling spaces) present
6. The number of gas-fired stoves present
7. The number of gas-fired dryers present
8. Anything else that runs on gas (i.e., separate domestic hot water heaters, etc.)
9. The input of the boiler (or boilers if there are more than one boiler)
10. Whether or not a dual fuel burner is in place or will be in place
11. Whether the boilers are scheduled to be replaced or not (for calculation of efficiency gains)
12. Whether this location intends to go on firm or interruptible gas

Appendix D:

Recommended residential and commercial building rules that will help reduce usage of heating fuel

Recommended residential and commercial building rules that help conserve heating fuel

- Thermostatic radiator valves (TRVs) or shutoff valves need to be installed on all radiators so that radiators' heat can be reduced or turned off altogether. If there are radiator covers, the regulator of the TRVs should be installed outside of the radiator cover.
- Radiators must be accessible for maintenance. Any radiator covers that are installed must open up so that the steam trap and shutoff valve are accessible.
- Residents need to get permission from the building management to replace cast iron radiators if the new radiator is smaller or only a steel radiator. The building management needs to be able to ensure that enough heat remains in the radiator when the heating system is turned off so that any given room gets enough heat.
- Owners should not be allowed to replace radiators with packaged terminal air conditioners (PTAC), which combine heating and air-conditioning in one through-the-wall unit. PTAC heat coils do not retain as much heat as cast iron radiators, which could lead to a resident not getting enough heat. Building managers should avoid overheating a majority of apartments just because a few residents replaced their cast iron radiators with insufficient radiators or PTACs.
- Residents should be required to remove the window air-conditioning units during the heating season because warm air often escapes through the units.
- If there are single-glazed windows, the building management should work on a window replacement plan.

Appendix E:

List of NYSERDA contractors that can help a building receive NYSERDA funding, an energy audit and efficiency measures

NYSERDA's web site has a list of contractors that are official NYSERDA partners and can help a building owner get NYSERDA funding, an energy audit and energy efficiency improvements for "existing multifamily buildings" or other buildings (we recommend using companies that are near New York City to reduce travel emissions). For an updated list go to:
www.getenergysmart.org/Resources/FindPartnerDetails.aspx?co=62

Green Building Technology International, Inc. www.greengurus.com Walter Elyon walter@greengurus.com 211 Brighton 15 Street Suite 3C Brooklyn, NY 11235 Phone: 347-374-3637	**Power Concepts, LLC** Tom Sahagian tsahagian@powerconceptsllc.com 29 Broadway, 12th Floor New York, NY 10006 Phone: 212-419-1900 Fax: 212-419-1990
Comfort Systems USA Energy Services www.comfortsystemsusa.com Albert LaValley albert.lavalley@comfortsystemsusa.com 50 Baker Hollow Road, Suite A Windsor, CT 06095 Phone: 860-687-0709 Fax: 860-687-1762	**Investment Engineering, Inc.** Matt Holden mholden@maine.rr.com 358 Main Street Yarmouth, ME 04096 Phone: 207-846-7726 Fax: 207-846-7728
Association for Energy Affordability, Inc. www.aeanyc.org David Hepinstall hepinstall@aeanyc.org 505 8th Ave, Suite 1801 New York, NY 10018 Phone: 212-279-3903 Fax: 212-279-5306	**Conservation Services Group, Inc.** www.csgrp.com Elizabeth Weiner Elizabeth.Weiner@csgrp.com 16 Court Street Suite 1801 Brooklyn, NY 11241 Phone: 347-442-3942 Fax: 718-522-3318

Daylight Savings Company www.daylightsavings.us Frank Lauricella flauricella@daylightsavings.us 25 Main St, Goshen, NY 10924 Phone: 845-291-1275 Fax: 845-291-1276	**ANP Energy Consulting Services Corp.** Asit Patel apatel@anpenergy.com 2492 Camp Avenue Bellmore, NY 11710 Phone: 516-304-1934 Fax: 516-409-9056
Community Environmental Center www.cecenter.org Richard M. Cherry 43-10 11th Street Long Island City, NY 11101 Phone: 718-784-1444 Fax: 718-784-8347	**Energy Investment Systems, Inc** Lewis Kwit lmk@eisincorp.com 515 Greenwich Street Suite 504 New York, NY 10013 Phone: 212-966-6641 Fax: 212-966-7010
NORGEN Consulting Group www.norgenconsulting.com Rafael Negron rafael.negron@norgenconsulting.com 127 Livingston Street 2nd Floor Brooklyn, NY 11201 Phone: 718-522-3736 Fax: 718-522-2533	**LC Associates** www.cutone.org Leonardo Cutone LeoCutone@aol.com 200 West 79th Street #10H New York, NY 10024 Phone: 212-579-4236 Fax: 646-383-8502
Camp Dresser & McKee www.cdm.com Christopher Korzenko KorzenkoCA@cdm.com 100 Crossways Park West Suite 415 Woodbury, NY 11797 Phone: 516-496-8400 Fax: 516-496-8864	**R3 Energy Management Audit & Review LLC** www.r3energy.com Rudy Scholl rudyscholl@att.net 1 Central Avenue Suite 311 Tarrytown, NY 01591 Phone: 914-489-0293, Fax: 914-909-3941
Integrated Energy Concepts Engineering, P.C. William Cristofaro bcristofaro@nrg-concepts.com 3445 Winton Place, Suite 102 Rochester, NY 14623 Phone: 585-272-4650	**Herbert E. Hirschfeld, PE** www.submeteronline.com Herbert Hirschfeld shakedad@aol.com 15 Glen Street, Suite 201, Box 744 Glen Cove, NY 11545 Phone: 516-759-2400

Fax: 585-272-4676	Fax: 516-759-2395
Johnson Controls www.jci.com Mark Turner Mark.T.Turner@jci.com 7612 Main Street Fishers Victor, NY 14564 Phone: 585-742-4844 Fax: 585-924-7086	**Performance Systems Development** www.psdconsulting.com Greg Thomas gthomas@psdconsulting.com 124 Brindley Street, Suite 4 Ithaca, NY 14850 Phone: 607-277-6240 Fax: 607-277-6224
EN-POWER GROUP Michael Scorrano mscorrano@en-powergroup.com 16 Frances Drive Katonah, NY 10536 Phone: 914-420-6507 Fax: 914-992-8048	**Optimira Energy** www.Optimira.com Richard McCarthy Richard.mccarthy@optimira.com 60 East 42nd Street New York, NY 10165 Phone: 212-867-9181 Fax: 212-867-9746
TAC Americas, Inc. www.tac.com Brian Ratcliff brian.ratcliff@tac.com 1100 Boulders Pkwy Suite 702 Richmond, VA 23225 Phone: 804-330-5660 Fax: 804-330-9002	**Antonucci & Associates, Architects and Engineers, LLP** aa-ae.com Nick Raad nraad@aa-ae.com 365 West 34th Street New York, NY 10001 Phone: 212-244-5060 Fax: 212-244-4271
Rand Engineering & Architecture, PC www.randpc.com Dave Brijlall info@randpc.com 159 West 25th Street 12th Floor New York, NY 10001 Phone: 212-675-8844 Fax: 212-691-7972	**Honeywell International Inc.** Cheryl McIntosh cheryl.mcintosh@honeywell.com 11 Century Hill Drive Latham, NY 12110 Phone: 978-395-1790 Fax: 781-823-6594
Memo-Cogen, Inc. www.energyportfolioassociates.com James Nadel jimnadel@aol.com 417 Center Ave	**Steven Winter Associates, Inc.** www.swinter.com Erica Brabon ebrabon@swinter.com 307 Seventh Avenue

Mamaroneck, NY 10543 Phone: 914-381-6300 Fax: 914-381-6303	Suite 1701 New York, NY 10001 Phone: 212-564-5800 ext 118 Fax: 212-741-8673
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Appendix F:

Blueprint for an Upper West Side building to switch fuel and increase efficiency

By Kathleen Tunnell Handel

During the fall of 2008, a group of shareholders from our 91-unit, 15-story New York City co-op formed a Green Committee to investigate how our building could reduce its carbon footprint. In researching various initiatives, we discovered an excellent way to make a significant impact on reducing the energy use and pollution output of our building while saving money. We would like to pass along what we've learned to other building managers and owners.

The umbrella here is the New York State Energy Research and Development Authority (NYSERDA), http://www.nyserda.org, the statewide public benefit corporation mandated to improve the state's economy while developing innovative solutions to some of the most difficult energy and environmental problems. Their many programs are independently funded through June 2011 by utility distribution surcharges paid into the system benefits charge (SBC) fund.

Because buildings account for one of the largest users of energy, NYSERDA funded the multifaceted New York Energy $martSM residential program that provides both financial and technical assistance for energy savings (http://www.getenergysmart.org/). As an existing multifamily residential building, our co-op falls within New York Energy $mart's multifamily performance program (MPP) and their existing buildings component, http://www.getenergysmart.org/MultiFamilyHomes/ExistingBuilding/BuildingOwner.aspx.

Step 1: Selecting and hiring your multifamily performance partner

The multifamily performance partner (Partner) acts as the NYSERDA gatekeeper and project manager for the Participant (building owners or managers). The Partner is to be hired from the network of approved MPP Partners for New York City (http://www.getenergysmart.org/Resources/FindPartnerDetails.aspx?co=62). The two prospective Partners that our co-op board interviewed, Community Environmental Center (CEC, www.cecenter.org) and R3 Energy Management Audit & Review LLC (www.r3energy.com), had very different styles in their presentations and proposals. We concluded that the requirements for being the Partner for market-rate housing was different than for affordable housing, based not only on the difference in NYSERDA eligibility requirements and financial incentive schedules but also in the building's ownership structure and decision-making process.

The important initial selection of our building's Partner was based on the positive references from numerous completed projects for buildings similar to ours as well as the level of experience in successfully navigating this complex process in a timely and financially responsible manner. Our building agreed to the preliminary scope of work detailed in R3 Energy's proposal and contracted with them as our MPP Partner.

Step 2: The Partner benchmarks the building's relative energy consumption and completes the energy audit for the Participants to review their energy-saving options

Once NYSERDA approves that the building's submitted application and participation agreement meets their minimal eligibility requirements, the Partner utilizes the required software benchmarking tool and performs a comprehensive energy audit of the building. That energy audit will be used to compare the building's current total energy consumption to that of similar multifamily buildings. The Partner then submits the resulting benchmark report and a proposed energy reduction plan (ERP) to the Participant, who reviews all the recommended potential energy reduction measures with their individual overall savings to investment ratio (SIR).

Our co-op became interested in working with NYSERDA as we were in the process of evaluating options to replace our aging low-pressure steam boiler. As a very costly expenditure with many technical details to consider, finding out that there was a state program in place that could help pay for us not only to work with a Partner, but also to help pay for the energy-saving projects we chose was a revelation. R3's initial proposal helped clarify the boiler questions the board had been faced with, such as whether to replace or repair the boiler, stay with oil fuel, have Con Edison run a line in from the street to use natural gas or to choose dual fuel enabling the building to use gas or oil based on cost, and whether to replace but still keep the old boiler as a potential back-up or to remove it altogether.

Step 3: The Participant works with the Partner to finalize the energy reduction plan that will achieve their energy reduction target and get NYSERDA approval

To be eligible for the available low-cost loans and larger financial incentives, the agreed-upon final scope of work needs to reduce the building's energy performance by 20% and the reduction substantiated over the required period of time. Measures that have historically produced favorable SIRs include replacing the boiler with a dual fuel system, upgrading the building energy management system for heating and installing a master electric meter with apartment submetering for building bulk-rate electricity purchasing. Our building is also reviewing options including energy-efficient lighting, a green roof and photovoltaic or solar panels.

Step 4: After the ERP is approved, the Partner helps bid the project out to any required third parties, such as the system's engineer and any contractors, while helping apply for the low-interest $martSM Loan and coordinating receipt of the first financial incentive payment

Bidding the project out and hiring and monitoring experienced and reliable contractors for the design, engineering and completion of the project is the next stage where the Partner is an invaluable aid to the Participant. The Partner also helps develop any financing strategy, including applying for a loan through the New York Energy $martSM Loan Fund (http://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.

NYSERDA brochures:

Multifamily Performance Program Overview:
www.getenergysmart.org/Files/Brochures/MultifamilyOverview.pdf

MPP Existing Buildings How To Participate Guide With Financial Incentives Table:
www.getenergysmart.org/Files/Brochures/ExistStepByStepFactSheet.pdf

What To Expect From Your MPP Partner:
www.getenergysmart.org/Files/Multifamily/MarketingMaterials/WhatToExpect8-28-07.pdf

Energy $martSM Loan Fund:

http://www.nyserda.org/loanfund/loanfundbrochure05.pdf

References

[1] For the full report go to: www.edf.org/dirtybuildings.

[2] See EPA web site for detailed information. Online resource is available at: http://www.epa.gov/oar/oaqps/greenbk/ .

[3] See http://www.stateoftheair.org/ .

[4] See http://www.stateoftheair.org/2009/health-risks/overview.html and also see *Residual Risks, The Unseen Costs of Using Dirty Oil in New York City Boilers*, a 2010 report by the New York Law School Institute for Policy Integrity, online resource at: http://www.policyintegrity.org/documents/ResidualRisks.pdf

[5] Residual fuel is also referred to as bunker fuel when it is burned in ships.

[6] According to the NYC Dept. of Environmental Protection database, about 6,813 buildings currently have active permits to burn either No. 4 or No. 6 oil, about an additional 2,000 buildings have No. 4 and 6 boiler permits "under review". Under review means that these are either buildings that previously burned No. 4 or 6 oil and are now applying for a renewal of the boiler permit. Under review can also stand for buildings that are brand new and are applying to burn No. 4 or 6 oil or buildings that are currently burning No. 2 heating oil but wish to switch to No. 4 or 6 oil. For the full database of buildings burning No. 4 or 6 oil including their addresses go to www.edf.org/dirtybuildings.

[7] Typically, only large buildings burn dirty heating oil (No. 4 or 6 oil) because of the increased maintenance involved. A "large" residential building would typically have at least 40 units.

[8] Researchers at the Columbia Center for Children's Environmental Health (CCCEH) have released a new paper that finds that exposure shortly after birth to ambient metals (i.e. nickel) from residual fuel oil combustion and particles (soot pollution) from diesel emissions are associated with respiratory symptoms in young children living in urban areas. December 2009 issue of the *American Journal of Respiratory and Critical Care Medicine*. http://www.ccceh.org/pdf-papers/Patel2009.pdf.

[9] There are approx. 900,000 buildings in New York City, including single family homes. 9,000 buildings is 1 percent of this but these 9,000 buildings are large buildings so 27% of the heating oil burned in NYC is dirty heating oil (No. 4 or 6 oil) that contributes 86% of the heating oil soot pollution because No. 6 oil is about 15 times more polluting in terms of soot pollution than No. 2 oil. 269 million gallons of No. 6 oil and 742 million gallons of No. 2 heating oil are burned in NYC. Each gallon of No. 6 burned creates 15 times more soot (PM) pollution than No. 2 heating oil according to the EPA emission standards. Total residual fuel numbers include No. 4 oil by allocating 50% to No. 2 oil and 50% to No. 6 oil. Specifically, of the 84 million gallons of No. 4 oil burned, we allocated 42 million gallons to No. 6 oil and 42 million gallons to No. 2 heating oil. The emissions factors shown in this report show that No. 2 oil produces 0.18 g/gal PM and No. 6 oil produces 2.71g/gal PM.

So: #6 PM = 227 mmgal x 15.29 = 3470.83 pollution units
4 PM = 84 mmgal x 10.6 = 890.4 pollution units
#2 PM = 700 mmgal x 1 = 700 pollution units
TOTAL PM 5061.23 pollution units
#6 and #4 oil PM pollution = 4361.23 ÷ 5061.23 = 86% of total PM from burning heating oil.

[10] This report will refer to total PM which includes PM_{10}, $PM_{2.5}$, ultrafine PM, and nano-sized PM.

[11] According to EPA's emission model MOBILE6.2, there are 1.13 million gasoline-powered vehicles in New York City and more than 108,000 diesel-powered vehicles.

[12] In New York City, residential, commercial and institutional heating systems release more than 30,000 tons of nitrogen oxides (NO_x), more than 17,000 tons of sulfur dioxide (SO_2) and more than 1,100 tons of soot or particulate matter every year. Over 750 tons/year of particulate matter come from buildings burning No. 4 or 6 oil. Data are from the EPA 2005 National Emissions Inventory. (NOx is a precursor to ozone.)

[13] The $242 million in asthma hospitalization costs in New York City are split up among the following payers: 49% by Medicaid, 23% by Medicare, 9% self-pay and 19% by others. See Asthma Facts, 2nd Ed. NYC Dept. of Health, 2003, p. 13. Online resource is available at http://www.nyc.gov/html/doh/downloads/pdf/asthma/facts.pdf .

[14] Jacobson, Mark Z., "Testimony for Hearing on Black Carbon and Global Warming," U.S. House of Representatives, Committee on Oversight and Government Reform, October 18, 2007; Bond, Tami C. and Haolin Sun, "Can Reducing Black Carbon Emissions Counteract Global Warming?" *Environ. Sci. Technol*. (2005), 39, 5921-5926.

[15] In 1985, the State Dept. of Environmental Conservation incorporated New York City's and other local standards in its regulation and adapted a default regulation of a 20,000 ppm cap for heating oil which has not changed since then. In comparison, New York City's regulation has capped sulfur levels at 3,000ppm for No. 6 oil and 2,000ppm for No. 2 heating oil.

[16] DEC Regulations Subpart 225-1. It is worth mentioning that the Mid-Atlantic/Northeast Visibility Union (MANE-VU) has formed a regional coalition of state governments from Maine to Maryland and the oil industry to improve air quality and visibility in the region. MANE-VU's plan is to lower the sulfur content of heating oil to 500 ppm by 2012 and 15 ppm by 2016 for No. 2 oil, and 2500-5000 ppm for No. 4 and No. 6 oil by 2012. Thus, this regional strategy does not improve upon the existing limits in New York City (3000 ppm) for No. 4 and 6 oil. Another major effort of MANE-VU is to improve heating system efficiency. Go to www.nescaum.org for more information.

[17] See http://www.epa.gov/ttn/chief/ap42/index.html for EPA emission's factors AP-42 for No. 2, 4 and 6 oil as well as natural gas. See also the table on page 35 of the report: AP-42 shows that PM emissions from burning No. 6 oil are 22.59 g/mmBtu, while they are only 1.32 g/mmBtu from burning #2 oil, which is a 94% reduction.

The PM numbers in this report only include the "filterable" portion of PM, not the "condensable" portion. Condensable PM is virtually all VOCs (which can condense to a liquid droplet in the atmosphere) not solid carbon. EPA's AP-42 emission factors have two different values for the emissions factor for No. 2 oil, one for "residential" boilers and one for "commercial" boilers. The value for commercial boilers is significantly higher, based on an assumption of using "older" burner technology as well as higher fuel sulfur levels. We chose to use the value for residential boilers for three reasons: 1. Number 2 oil in NYC has low sulfur content by law; 2. while the boilers in question (those currently burning No. 6 oil) are relatively large compared to the boiler in a typical 2 – 10 family "residential" building they are pretty small in comparison to true "commercial" boilers and are therefore more like residential boilers; and, 3. any new conversion to the use of No. 2 oil would use burners with "new" as opposed to old technology. MJ Bradley had a lengthy discussions with NYCDEP about these assumptions, and the NYCDEP agreed with these assumptions and emissions factors.

As to CO_2 emission rates, online resource is available at http://www.eia.doe.gov/oiaf/1605/excel/Fuel%20Emission%20Factors.xls.

The following are CO_2 emission rates for the different fuels:

Natural Gas:	117.6 lb/mmBtu
#2 Oil:	159.3 lb/mmBtu
#6 Oil;	166.7 lb/mmBtu

Compared to No. 2 heating oil, natural gas results in a 26% reduction in CO_2. Compared to No. 6 oil, natural gas results in a 29% reduction in CO_2. Efficiency gains also result in a one-for-one reduction in CO_2 (i.e .,10% reduction in fuel use [mmBTU] results in a 10% reduction in CO_2 emissions, all else being equal).

[18] A 2006 study found that nickel is particularly toxic and harmful to the cardiovascular system. Nickel emissions occur when No. 4 and 6 oil are burned and as a result, New York City has by far, the highest airborne nickel levels of any city in the country. On average, New York City's nickel concentrations are about 9 times higher compared to other U.S. cities. See Lippmann et al., Environmental Health Perspectives, Vol. 114, Number 11, November 2006. See also *Fresh Air Maybe Hazardous To Yur Health And In NYC, it may be downright deadly, warns Dr. Morton Lippmann*, published in NYU Physician Summer 2008. Online resource at: http://communications.med.nyu.edu/publications/nyu-physician/summer-2008

[19] Source: New York City Department of Environmental Protection. See chart below:

#2 Oil	Floor Area ft^2	
Boro	Non-Residential	Residential
Manhattan	76,869,742	183,433,783
Bronx	39,748,838	70,733,394
Brooklyn	66,444,967	201,810,036
Queens	85,309,338	117,397,931
Staten Island	12,672,854	8,228,263
Total	281,045,739	581,603,407

#4 Oil	Floor Area ft^2	
Boro	Non-Residential	Residential
Manhattan	37,090,951	65,489,989
Bronx	5,068,627	54,715,863
Brooklyn	14,561,875	15,084,597
Queens	13,999,112	29,055,404
Staten Island	791,123	1,425,279
Total	71,511,688	165,771,132

#6 Oil	Floor Area ft^2	
Boro	Non-Residential	Residential
Manhattan	107,877,191	255,934,426
Bronx	9,048,370	111,726,558
Brooklyn	7,272,890	50,718,753
Queens	12,757,833	80,727,649
Staten Island	1,506,762	3,345,791
Total	138,463,046	502,453,177

DEP chart of number of buildings burning No. 2, 4 or 6 oil (DEP does not regulate one- or two-family homes or boilers less than 350,000 Btu/hr, so these buildings are not represented in this chart. One- or two-family homes typically burn No. 2 heating oil or natural gas).

	# of units using #4 oil		# of units using #6 oil		# of units using #2 oil	
	Non-Residential	Residential	Non-Residential	Residential	Non-Residential	Residential
Manhattan	382	1,240	505	2,044	1,665	6,822
Bronx	63	1,148	51	1,227	815	2,645
Brooklyn	105	302	48	425	1,265	7,427
Queens	104	352	49	714	1,385	3,302
Staten Island	7	8	5	16	147	100
Total	661	3,050	658	4,426	5,277	20,296

[20] To access an interactive map of all the buildings burning No. 4 or 6 oil go to: www.edf.org/dirtybuildings. The NYC Department of Buildings has the most up to date database on the buildings' boilers and what fuel they are burning. Go to: http://www.nyc.gov/html/dob/html/home/home.shtml and enter the building address you want to check.

[21] New York City Department of Environmental Protection, Boiler Inventory database. Energy Policy Research Foundation, Inc., "Costs and Supply Risks to Prohibition On the Use of No. 4 and No. 6 Oil in New York City," preliminary report, February 12, 2009, and EPA AP-42 (5th ed.) chapter 1. Some buildings have more than one boiler. The DEP database shows close to 9,000 buildings with active permits burning No. 4 or 6 oil. See www.edf.org/dirtybuildings for a full list.

[22] Information provided by the heating oil industry. EDF could not find any other source specifying the amount of No. 2 heating oil burned in NYC annually.

[23] Numbers include No. 4 oil by allocating 50% to No. 2 oil and 50% to No. 6 oil. Specifically, of the 84 million gallons of No. 4 oil burned, we allocated 42 million gallons to No. 6 oil and 42 million gallons to No. 2 heating oil.

[24] These numbers are based on the New York City Dept. of Environmental Protection (DEP) boiler database. The DEP only regulates boilers that are 350,000 Btu/hr or larger.

[25] There are approximately 900,000 buildings in New York City. (see http://www.nyc.gov/html/dob/html/news/commissioner_faia.shtml) These smaller buildings have smaller boilers that are not regulated by the DEP. See note above.

[26] See calculation in Endnote No. 9.

[27] See NYU Physician Summer 2008: *Fresh Air May Be Hazardous To Your Health,* by Dr. Morton Lippmann. Online resource available at: http://webdoc.nyumc.org/nyumc/files/communications/u2/summer2008_Cover.pdf

[28] For a complete list of all states go to http://tonto.eia.doe.gov/dnav/pet/pet_cons_821rsd_dcu_SVT_a.htm and check for category "commercial" which represents the residual oil used for heating purposes.

[29] The states listed have significantly lower total usage of residual fuel compared to New York State. For detailed numbers see http://tonto.eia.doe.gov/dnav/pet/pet_cons_821rsd_dcu_SVT_a.htm

[30] The requirements that need to be met to qualify as a low income buildings under a DEP rule still need to be worked out but could be similar to the requirements under the federal

weatherization assistance program (WAP) managed by the U.S. Dept. of Energy, see http://www.dhcr.state.ny.us/programs/weatherizationassistance/index.htm).

[31] By switching from No. 6 oil to natural gas, annual heating-related PM, NO_x and SO_2 emissions from a 200-unit apartment building could be reduced by 205 pounds, 1,482 pounds and 1,692 pounds, respectively.

[32] Based on the average U.S. Class 6 truck, which travels 12,800 miles per year (USDOE) and emits 0.22 g/mi PM (USEPA, calendar year 2007 fleet average).

[33] Created in 1955, the Mitchell-Lama program provides affordable rental and cooperative housing to moderate- and middle-income families. See http://www.nyc.gov/html/hpd/html/apartment/mitchell-lama.shtml.

[34] Check with your utility company to find out if they pay to bring the gas line or if your building has to pay for the gas line in case the building wants to get the interruptible gas rate (cheapest rate). Sometimes buildings need to pay for the gas line themselves if they opt for the interruptible gas rate which means that it is beneficial to split the costs with neighboring buildings that also want to switch to natural gas. Sometimes the utility company will pay to bring the gas lines to the buildings and still lets them use the interruptible gas rate if enough buildings switch at the same time. It's best to discuss this with the utility company (National Grid for Staten Island, Brooklyn and southern part of Queens. Con Edison for northern part of Queens, Manhattan and the Bronx).

[35] When you enter your building's address you will see information about the building, ECB violations, etc. To the right of the ECB box you will see a series of links. The bottom link is for DEP boiler database. Click on DEP boiler database to see what fuel a building is burning. When EDF tested the database, there was no boiler information for some of the addresses. If this is the case, check the list on our web site at www.edf.org/dirtybuildings, or ask your managing agent.

[36] For Consolidated Edison contact (for buildings in Manhattan, part of Queens), go to www.coned.com/naturalgas or call 1-800-643-1289; National Grid contact (for buildings in Queens, Brooklyn, Staten Island), go to http://www2.nationalgridus.com/myngrid/, or call 1-877-MyNGrid (877-696-4743).

[37] Summary of potential conversion costs:
Conversions incur no incremental costs if the conversion happens at end of the useful life of the boiler/burner (25-35 yrs. for boilers (up to 60 if maintained and overhauled) and 20 years for burners);

- $15,000-30,000 (2 men, 3 days) for basic conversion from No. 6 oil to No. 2 heating oil
    - $5,000-10,000 to remove preheater and electric heater, repipe;
    - $5,000-10,000 to clean tank, steam lines;
    - $5,000-10,000 for burner "setup" to burn with proper air mix (improves efficiency by 15-20%, from 65-70% burn to 85% burn);
    - Burners less than 20 years old can be adjusted to burn all fuels; specs for dual fuel burners are somewhat different; the cost is $4,000;
- $40,000-60,000 for complete burner replacement, including electrical and filings
- Extras
    - $1,000-2,000 for low NOx burner (not available for No. 6 oil);
    - $6,000 for optional closed-loop oxygen system; boosts efficiency 2-10%;
    - $50,000 for economizer (heat exchanger in flue); boosts efficiency 5%, but these are bulky and unwieldy and are vulnerable to sulfur;

- Tank removal costs can be significant but may be inevitable under LUST regulations.

[38] Con Edison quoted an "interruptible" price of $1.13/therm of natural gas. One gallon of No. 6 oil contains about 150,000 Btu of energy, while one therm of natural gas contains 100,000 Btu. Therefore, the calculation is as follows: (150,000÷100,000) X 50,000 = 75,000 therms/year of natural gas needed. Multiply this by $1.13/therm as quoted by Con Edison for a total of about $84,750.

[39] See http://www.cecenter.org/?page_id=27 for more information.

[40] Go to www.edf.org/dirtybuildings.

[41] In a combustion efficiency (CE) test the heating system contactor measures how much fuel gets turned into usable heat, which shows whether the boiler and burner are running as efficiently as possible. The following gets performed in a CE test:

- stack temperature test
- measure percentage of CO_2 in exhaust
- draft test
- smoke test
- measure percentage of CO if natural gas is burned.

Information provided by Fred Goldner of EMRA; see www.emra.com.

[42] For more details about efficiency measures to reduce a building's electricity consumption, please refer to chapter 6 online.

[43] The potential fuel savings shown in the chart apply only if each measure is the only one undertaken. For example, if an EMS has been installed, TRVs will help with individual comfort issues, but building-wide savings will be smaller than shown here.

[44] *The influence of location, source, and emission type in estimates of human health benefits of reducing a ton of air pollution* by Neal Fann, Charles M. Fulcher and Bryan J. Hubbell, June 9, 2009. U.S. EPA, Office of Air Quality Planning and Standards. See http://www.springerlink.com/content/1381522137744641

[45] See EPA wegpage: http://www.epa.gov/pmdesignations/2006standards/final/region2.htm

[46] See NYSERDA webpage: www.getenergysmart.com.

[47] One inquiry with Con Edison for a building on the Upper West Side has shown that it would cost Con Edison about $250,000 to bring a natural gas line to one building. Con Edison pays for the gas line if the building only burns natural gas and pays the firm gas rate. However, the building owner has the option of paying for the line and instead choosing the cheaper interruptible gas rate. Lastly, the building owner can try to convince nearby buildings to switch to dual fuel natural gas/No. 2 heating oil, in which case Con Edison pays for the line and lets all the buildings in that area go on dual fuel with the cheaper interruptible gas rate.

[48] According to EPA's emission model MOBILE6.2 there are 1.13 million gasoline powered vehicles in NYC and more than 108,000 diesel powered vehicles.

[49] Data from EPA 2005 National Emissions Inventory.

[50] There are approx. 900,000 buildings in New York City, including single family homes. 9,000 buildings is 1 percent of this but these 9,000 buildings are large buildings so 27% of the heating oil burned in NYC is dirty heating oil (No. 4 or 6 oil) that contributes 87% of the heating oil soot pollution because No. 6 oil is 18.8 times more polluting than No. 2 oil. 269 million gallons of No. 6 oil and 742 million gallons of No. 2 heating oil are burned in NYC. Each gallon of No. 6 burned creates 18.8 times more soot (PM) pollution than No. 2 heating oil according to the EPA emission standards. Total residual fuel numbers include No. 4 oil by allocating 50% to No. 2 oil and 50% to

No. 6 oil. Specifically, of the 84 million gallons of No. 4 oil burned, we allocated 42 million gallons to No. 6 oil and 42 million gallons to No. 2 heating oil.
The emissions factors shown in this report show that No. 2 oil produces 0.18 g/gal PM and No. 6 oil produces 3.39 g/gal PM. No. 6 oil produces 18.8 times as much PM per gallon than No. 2 oil.

So: #6 PM = 268 mmgal x 18.8 = 5057.2 pollution units
#2 PM = 742 mmgal x 1 = 742.0 pollution units
TOTAL PM 5799.2
#6 = 5057.2 ÷ 5799.2 = 87% of total PM from burning fuel oil.

[51] Data from EPA 2005 National Emissions Inventory.

[52] Most of the nitrogen and oxygen comes from the air, but both fuel-bound nitrogen and oxygen from oxygenated fuels can contribute to NOx formation.

[53] American Heart Association, American Heart Association Scientific Statement, "Air Pollution is Serious Cardiovascular Risk," June 1, 2004.

[54] A 2006 study found that nickel is particularly toxic and harmful to the cardiovascular system. Nickel emissions occur when No. 4 and 6 oil are burned and as a result, New York City has by far, the highest airborne nickel levels of any city in the country. On average, New York City's nickel concentrations are about 9 times higher compared to other U.S. cities. See Lippmann et al., Environmental Health Perspectives, Vol. 114, Number 11, November 2006. See also *Fresh Air Maybe Hazardous To Yur Health And In NYC, it may be downright deadly, warns Dr. Morton Lippmann*, published in NYU Physician Summer 2008. Online resource at: http://communications.med.nyu.edu/publications/nyu-physician/summer-2008

[55] Source: Morton Lippmann, PhD and Richard E. Peltier, PhD, Seasonal and Spatial Distributions of Nickel in New York City Ambient Air, ISES–ISEE 2008 Joint Annual Conference, Pasadena, CA (adopted from paper in press in J. Expos. Sci & Environ. Epidemiol.)

[56] Researchers at the Columbia Center for Children's Environmental Health (CCCEH) have released a new paper that finds that exposure shortly after birth to ambient metals (i.e. nickel) from residual fuel oil combustion and particles (soot pollution) from diesel emissions are associated with respiratory symptoms in young children living in urban areas. December 2009 issue of the *American Journal of Respiratory and Critical Care Medicine*. http://www.ccceh.org/pdf-papers/Patel2009.pdf.

[57] See EPA webpage at: http://www.atsdr.cdc.gov/toxprofiles/phs15.html#bookmark05

[58] The Free Dictionary, Definition: Boiler, http://www.thefreedictionary.com/boiler (accessed August 14, 2008).

[59] Many stream boilers in New York City are controlled by a thermostat that measures outdoor air temperature rather than internal room temperature to determine when and how long to run the burner to make stream. This method of burner control is much less efficient

[60] American Council for an Energy-Efficient Economy, "Heating Systems: Furnaces and Boilers," http://www.aceee.org/consumerguide/heating.htm (accessed September 3, 2008).

[61] Fuel Merchants Association of New Jersey, "Guide to Oil Heat Storage Tanks," www.fmanj.org/pdf/FMATankBrochure.pdf (accessed August 15, 2008).

[62] High Performance HVAC, "Gas Furnace Components," http://highperformancehvac.com/gas-furnace-components.html (accessed August 15, 2008).

[63] According to the EIA web site. Online resource is available at http://www.eia.doe.gov/oiaf/1605/excel/Fuel%20Emission%20Factors.xls.

The following are CO2 emission rates for the different fuels:

Natural Gas:	117.6 lb/mmBtu
#2 Oil:	159.3 lb/mmBtu
#6 Oil;	166.7 lb/mmBtu

Compared to No. 2 heating oil, natural gas results in a 26% reduction in CO2. Compared to No. 6 oil, natural gas results in a 29% reduction in CO2. Efficiency gains also result in a one-for-one reduction in CO2 (i.e .,10% reduction in fuel use [mmBTU] results in a 10% reduction in CO2 emissions, all else being equal).

[64] For example, Nassau County and Westchester County can burn No. 6 fuel with sulfur contents of 3,700ppm and in Suffolk County the sulfur content can go up to 10,000ppm. Some Counties in New York State can burn fuel up to 15,000ppm in sulfur content.

[65] Btu stands for British thermal unit. Btu is a unit of power defined as the amount of energy required to raise the temperature of one pound of liquid water by one degree Fahrenheit.

[66] Energy Information Administration, *Annual Energy Outlook 2009, Table 3 Energy Prices by Sector and Source*; Report #:DOE/EIA-0383(2009), March 2009; *http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html;* All prices quoted are in 2007 dollars and are projected prices for commercial customers in the EIA reference case.

[67] A basic soot blower consists of a rotating nozzle attached to a steam, water or air line. The nozzle is rotated using a motor (automatic) or chain fall (manual). The rotating nozzle directs the steam, water or air at the pipes and heat exchanger, and dislodges ash and soot. The ash and soot are then carried out the exhaust stack.

[68] Energy Information Administration, *Annual Energy Outlook 2009, Table 3 Energy Prices by Sector and Source;* Report #:DOE/EIA-0383(2009), March 2009; *http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html;* All prices quoted are in 2007 dollars and are projected prices for commercial customers in the EIA reference case.

[69] Energy Information Administration, *Annual Energy Outlook 2009, Table 3 Energy Prices by Sector and Source;* Report #:DOE/EIA-0383(2009), March 2009; *http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html;* All prices quoted are in 2007 dollars and are projected prices for commercial customers in the EIA reference case.

[70] Information provided by Sprague Energy.

[71] Massachusetts Oilheat Council & National Oilheat Research Alliance, "Combustion Testing of a Biodiesel fuel oil blend in Residential Oil Burning Equipment," July 2003, http://www.biodiesel.org/resources/reportsdatabase/reports/hom/20030801_htg-002.pdf (accessed November 13, 2008) and Biodiesel for Heating of Buildings in the United States, NYSERDA. Online resource available at: http://www.bnl.gov/est/erd/biofuel/files/pdf/AlbrechtKrishnaPaper.pdf

[72] Biodiesel for Heating of Buildings in the United States, NYSERDA. Online resource available at: http://www.bnl.gov/est/erd/biofuel/files/pdf/AlbrechtKrishnaPaper.pdf

[73] Ibid.

[74] Ibid.

[75] The National Biodiesel Board (http://www.biodiesel.org/) has a section (http://biodiesel.org/askben/) for questions on heating applications. Interested persons can submit via e-mail questions about biodiesel and receive responses within 24 hours or less.

[76] Pacific Gas and Electric Company, "What is Natural Gas?," http://www.pge.com/microsite/safety_esw_ngsw/ngsw/basics/whatis.html (accessed August 20, 2008).

[77] A standard cubic foot of natural gas is measured at 60°F at a pressure of 14.73psia.

[78] Energy Information Administration, *Annual Energy Outlook 2009, Table 3 Energy Prices by Sector and Source;* Report #:DOE/EIA-0383(2009), March 2009; *http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html;* All prices quoted are in 2007 dollars and are projected prices for commercial customers in the EIA reference case.

[79] By switching from No. 6 oil to natural gas annual heating-related PM, NO_x and SO_2 emissions from a 200-unit apartment building could be reduced by 205 pounds, 1,482 pounds and 1,692 pounds, respectively.

[80] Based on the average U.S. Class 6 truck, which travels 12,800 miles per year (USDOE) and emits 0.22 g/mi PM (USEPA, calendar year 2007 fleet average).

[81] Consumer Energy Council of America (CECA), "Smart Choices for Consumers: Analysis of the Best Ways to Reduce High Heating Costs, Section D: Upgrading Existing Equipment," p. 12, November 2005.

[82] State Supply Company, "Steam Pipe Insulation," http://www.statesupply.com/displayItem.do?sku=IF1010X (accessed November 13, 2008).

[83] Conversations with Barry Allen and Robert Mucci from National Grid discussing boiler upgrades, May 7, 2008.

[84] Consumer Energy Council of America (CECA), "Smart Choices for Consumers: Analysis of the Best Ways to Reduce High Heating Costs, Section D: Upgrading Existing Equipment," p. 12, November 2005.

[85] Switching to distillate fuel will reduce sootblowing requirements (~$1,000–2,000) as well as reduce the need for boiler efficiency tune-ups (~ $1,000).
Removing the heated residual fuel storage tank would result in a savings of $1,000 annually, assuming a 2kW heater operating for 7,000 kWh annually.

[86] Conversations with Barry Allen and Robert Mucci from National Grid discussing boiler upgrades, May 7, 2008.

[87] We recommend that all natural gas users consider having their gas meters calibrated annually for accuracy in therm usage, especially for large systems.

[88] Conversations with Barry Allen and Robert Mucci from National Grid discussing boiler upgrades, May 7, 2008.

[89] New York State Uniform Fire Prevention and Building Code, §F603 Fuel Fired Appliances - §F603.6.1 Masonry chimneys, http://www.cortland.org/CITY/fire/statecode-fuelfired.htm (accessed September 26, 2008).

[90] Consumer Energy Council of America (CECA), "Smart Choices for Consumers: Analysis of the Best Ways to Reduce High Heating Costs, Section D: Upgrading Existing Equipment," p. 12, November 2005.

[91] 75% x 10,000 gallons x 150,000 Btu/gal = 1,125,000,000 Btu, or 1,125 mmBtu.

[92] Assumes that interruptible gas rate will be 23% lower than standard commercial rate, per current pricing structure in New York City.

[93] Conversations with Barry Allen and Robert Mucci from National Grid discussing boiler upgrades, May 7, 2008.

[94] Using natural gas will reduce the need for sootblowing (~$500) and the need for boiler efficiency tune-ups (~$500). Maintenance practices when using the backup fuel will be normal No. 6 procedures.

[95] Conversations with Barry Allen and Robert Mucci from National Grid discussing boiler upgrades, May 7, 2008.

[96] Conversations with Barry Allen and Robert Mucci from National Grid discussing boiler upgrades, May 7, 2008.

[97] Assuming $2.60/gallon for No. 2 fuel oil and $11.11/mmBtu interruptible rate for natural gas.

[98] Conversations with Barry Allen and Robert Mucci from National Grid discussing boiler upgrades, May 7, 2008.

[99] U.S. Department of Energy, Energy Efficiency and Renewable Energy, "Your Home," boiler retrofit options, http://apps1.eere.energy.gov/consumer/your_home/space_heating_cooling/index.cfm/mytopic=12550 (accessed August 10, 2008).

[100] Washington State University, Energy Efficiency Fact Sheet, "Boiler Combustion Monitoring & Oxygen Trim Systems," http://www.energy.wsu.edu/documents/engineering/boiler_comb.pdf (accessed June 20, 2008).

[101] Conversations with Barry Allen and Robert Mucci from National Grid discussing boiler upgrades, May 7, 2008.

[102] Oil Heat America, "Oil Heat Equipment—Burners," http://www.oilheatamerica.com/index.mv?screen=burners (accessed August 28, 2008)

[103] Conversations with Barry Allen and Robert Mucci from National Grid discussing boiler upgrades, May 7, 2008.

[104] See http://www.cecenter.org/?page_id=27 for more information.

[105] In a combustion efficiency (CE) test the heating system contactor measures how much fuel gets turned into usable heat, which shows whether the boiler and burner are running as efficiently as possible. The following gets performed in a CE test:

- stack temperature test
- measure percentage of CO_2 in exhaust
- draft test
- smoke test
- measure percentage of CO if natural gas is burned.

Information provided by Fred Goldner of EMRA; see www.emra.com.

[106] The potential fuel savings shown in the chart apply if each measure is the only one undertaken. For example, if an EMS has been installed, TRVs will help with individual comfort issues, but building-wide savings will be smaller than shown here.

[107] See note 2, above.

[108] This is also true in the summer if the boiler is used to provide hot water for kitchens and baths as well as for space heating.

[109] U.S. Department of Energy, Energy Efficiency and Renewable Energy, "Your Home," Thermostats and Control Systems, http://www.eere.energy.gov/consumer/your_home/space_heating_cooling/index.cfm/mytopic=12720 (accessed August 28, 2008).

[110] "Shoulder" periods refer to times when some heat is needed, but well below peak needs – above 40oF outdoors, for instance. This is when the load on the heating system is low, but it can't be shut off.

[111] Internet search using keywords "programmable thermostat price"

[112] See note 8, above.

[113] Energuard can provide such a system. See http://www.ec4h.com/divisions/Energy/ENERGUARD1.pdf.

[114] Data provided by www.peconiccontrols.com.

[115] See http://www.cecenter.org/?page_id=27 for more information.

[116] Ibid.

[117] Building Green.com, Environmental Building News, Energy Metrics: Btu's, Watts, and Kilowatt-Hours, accessed on September 26, 2008, http://www.buildinggreen.com/auth/article.cfm?fileName=161220a.xml.

[118] U.S. Department of Energy, Energy Information Administration, 2001 Residential Energy Consumption Survey: Household Energy Consumption and Expenditure Tables, Table 2. Fuel Oil Consumption and Expenditures in U.S. Households by End Use and Census Region, 2001; Average for Northeast Region; this is 630 gallons of fuel oil.