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Auditing the All-Electric Multifamily Building

By Vicky Hayes

A rehabbed, all-electric multifamily building can give an auditor one whale of a headache—or the satisfaction of a job well done, if idiosyncrasies are transformed into insights.

From an Auditor's Journal:

August 7, 1991 (Initial visit notes): We're standing in front of a beautifully renovated, four-story brick building in upstate New York wondering how we're ever going to figure out what's wrong with a building that looks so nice, but uses so much electricity. It houses a low-income senior citizen population, currently at war with its desperate building management company over fuel costs. Our fuel analysis says the potential for fuel savings is here—but where?

The Electrically Heated Multifamily

Multifamily buildings can be intimidating to the energy auditor because of their size and complexity. Electrically heated multifamily buildings are even more scary because of their building design idiosyncrasies:

- Each apartment has its own heat source and controls. This also usually means the apartments have individual electric meters, which can make doing a fuel analysis into a three-ring circus.
- Electric heating systems are, by the nature of resistance heating, already 100% efficient—no help for fuel savings there.
- In places where one would normally look for fuel savings, such as interior lighting, the post-retrofit loss of internal heat gain normally found during the heating season can offset any electricity conserved.
- Baseboard strip heating has the lowest installation cost of any heating source. Developers who specify it are probably looking for a way to cut construction costs. This means they probably took other shortcuts such as inadequate installation of insulation, low-cost non-calibrated thermostats, poor wall design, and incorrect installation of ventilation systems.

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Add two and two—an expensive type of energy and a building with severe energy-loss problems—and what do you have? In some cases, tenants paying more for electricity than for rent!

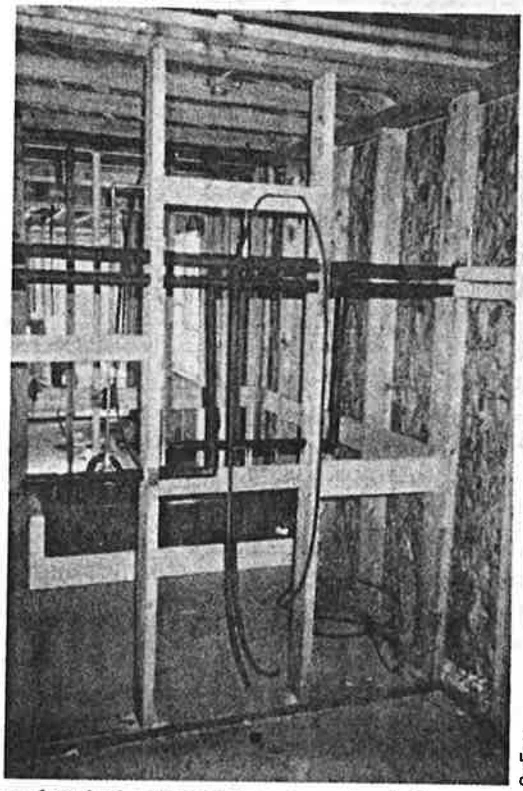
Preparing for the Audit

To determine how much the building can save, one must know how much it uses. The auditor can use weather-normalizing software like PRISM to figure heating energy use. This permits comparisons with heating energy consumptions from other time periods. The analysis also attempts to disaggregate—or distinguish—the kilowatt-hours for heating or cooling usage from the base-load usage: the sum of domestic water heating, lighting, and other uses. (Most energy software routines cannot both normalize heating and cooling loads at the same time.) This helps the auditor focus on the any usage that exceeds what it should be. (See "PRISM: A Tool for Tracking Retrofit Savings," *HE*, Nov/Dec '87, p. 27, and "Now That I've Run PRISM, What Do I Do With The Results," *HE*, Sept/Oct '90, p. 27.)

Learning how to use this type of software is not easy, and for electric multifamily buildings with individual fuel histories, running the analysis is time consuming. But the result is invaluable—a fuel usage analysis that reveals a "profile." Profiling, or graphing the fuel usage by location (by unit location or by floor) helps target areas of the building for special investigation during the audit. The auditor can zero in on problem areas even further by looking at the "as-builts," building plans revised during construction, keeping the fuel usage profile in mind.

October 17, 1991 (Notes on fuel analysis results): The 42 individual fuel histories for common areas and apartments have been weather normalized and disaggregated using PRISM. We profiled the usage by floor and by apartment location to see if we would find anything interesting. We did! Contrary to what we expected, the top floor has the highest electric usage. In addition, looking at the graphs by location, we see corner apartments on all floors are high users.

AUDITOR'S NOTEBOOK



SyrEsco

Here, electrical, plumbing, and mechanical systems are being installed before interior walls are finished. Many adaptations of original building plans occur at this point of construction. "As builts," plans which have been updated to include actual construction changes, are a valuable resource, allowing the auditor to know what is actually inside the walls.

November 20, 1991 (Notes on building plan review): Reviewed the "as-builts" with profile in mind. Original building was a flat-roof, brick-construction, four-story factory with no interior partition walls. Ceilings were 12 ft high, open-beam, wood-slat ceilings. Converted in 1982 to 41 apartments for senior citizens. Special note: Central ventilation system on each floor with separate ducting for kitchens and baths. Greatest ceiling drop was on fourth floor.

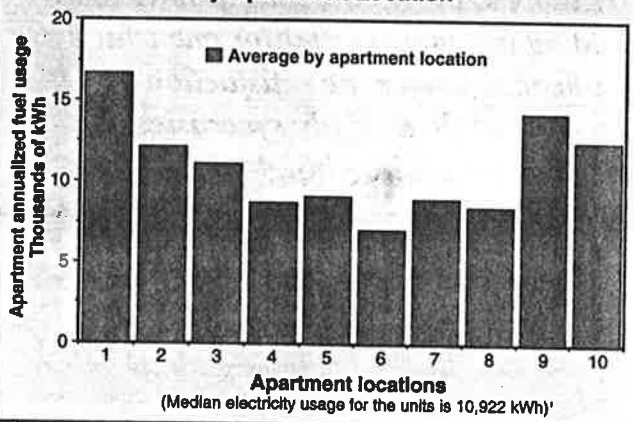
The Audit

After preparing for the audit comes the actual building investigation, hopefully a thorough one. "Thorough" does not mean going into every unit. Audit investigations should be guided by the use profile, building plans, and then, additionally, a look at typical units, though not necessarily the high usage one. A quick run-through of necessary equipment includes blower door(s), infrared camera, hand tools, thermometers, humidistat, and water flow measurement devices, and the most critical tool for any audit—an observant, attentive human: the auditor.

Unlike those with oil or gas, electrically heated multifamily buildings do not require much in the way of testing to diagnose heating system efficiency. All-electric apartments rarely have distribution systems since most have some form of strip heat. However, poorly functioning or broken heating controls are common. Most thermostats are not even numerically calibrated. Incorrectly wired heating controls are also typical. Therefore, it is critical to test thermostats for accuracy and deadband range. Tenants who have thermostats without numbers, but with pseudo-calibrations demarcated by words like "Comfort Zone," tend to develop tolerance for "comfort"—in the 75°F–80°F range.

Next, the thermal envelope requires a good look. If, as in 90% of all-electric construction, the builders attempted to keep initial costs down, another common place they may have cut corners is the building shell. Building codes usually require a minimum R-value for walls and ceilings, but if the insulation is poorly installed, it will perform substantially below its rated value. Holes cut for plumbing and wiring and inexpensive sidings contribute to free air movement in and through wall cavities.

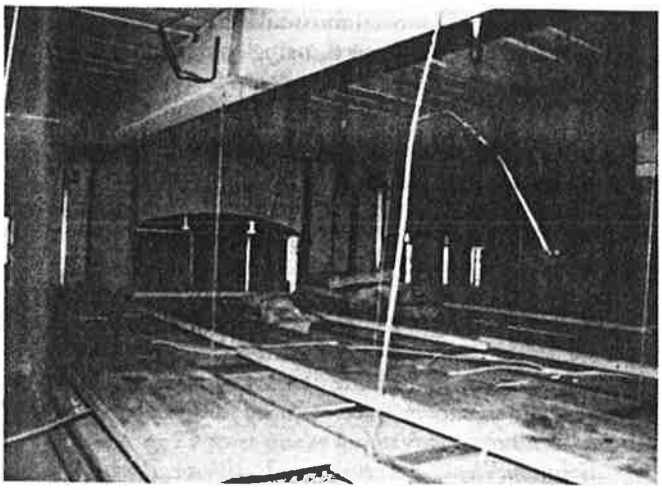
Figure 1. Average Annual Pre-Retrofit Usage by Apartment Location



The most influential air movement, in fact, happens in the wall cavities themselves. "Wall washing" is air passing along the drywall in the wall cavity, causing conductive heat loss and requiring augmenting the insulation. This will become obvious with an infrared scan during the heating season. In rehabilitation construction, the practice of building new interior walls within the old and leaving a gap between the two allows plenty of free air movement.

On the other hand, contrary to what one may expect, the interiors of the units themselves tend to have very little air infiltration, often below the ASHRAE guidelines specifying 15 cfm per person. The lack of supply oxygen or exhaust venting, normally provided for combustion appliances, may be responsible for this excessive air-tightness. Regular maintenance aids in air sealing. For example, painting or wall repair, usually performed when the unit changes tenancy, may also contribute to low infiltration.

It is important for the auditor to understand that tenants tend to blame building management and/or the utility for a building's high energy usage problems. Conversely, management may blame tenant behavior for high utility bills. In an all-electric building the higher cost of this particular energy aggravates finger pointing. To avoid heightening tensions, audit findings should be discussed with the building owner only. In addition, it's up to the auditor to



EnTherm, Inc.

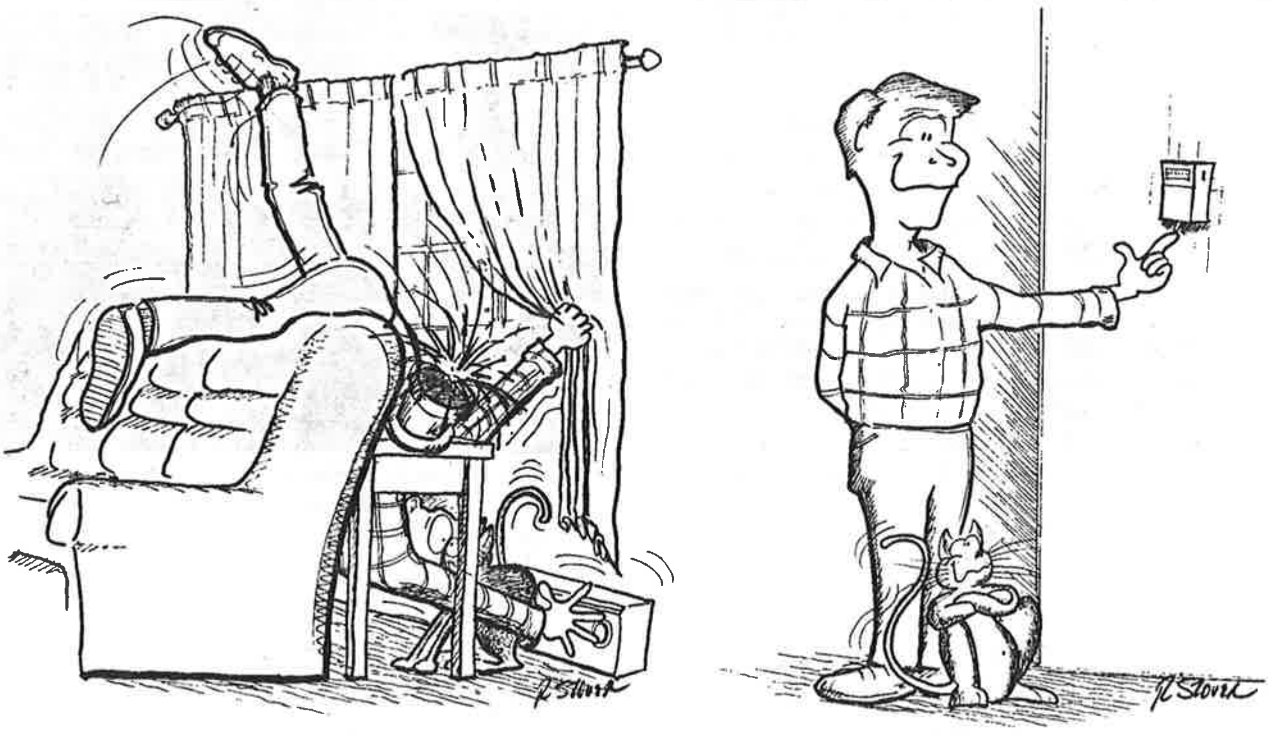
Auditors at the Steinhorst Square complex found the apartments were built as a series of boxes within the frame of the original factory building. Massive gaps created severe convection currents.

determine what can realistically be expected of tenants, assessing not only where energy is lost, but how it is being used. This view should be shared with the building owner. For instance, tenants can't be expected to crawl behind furniture to adjust knobs on ten different baseboard heaters. By the same token, it's surely reasonable to ask them not to keep the thermostats on "high" while controlling the indoor temperature with the "double hung zone valves"—the windows.

November 21, 1991 (Audit day one, field notes): The rehabilitation consisted of building sheetrock "boxes" with aluminum stud walls within the old brick walls of the factory. These boxes would eventually become the apartments. Each floor has ten apartments, two two-bedrooms and eight one-bedrooms with a central corridor, two stairways, and an elevator.

Exterior infra-red scan revealed excessive heat loss on all floors from central exhaust system grilles when ventilation system was operating. Kitchen exhaust system runs 12 hours a day, bathroom 17 hours. When system is not in operation, grilles exhibit heat loss from floors three and four, and no indication of loss from floors one and two. No dampers found in exhaust ducting. Did blower door tests on 12 units and found average natural cfm (cfm_{50} divided by 16.2) to be 19.29. Hallways tested tight as well. Obviously couldn't depressurize such a large building. Occupants reported that the apartments felt drafty. They had pinpointed bath and kitchen exhaust vents as a major source of drafts. Many had taped over the grilles. All agreed that fourth (top) floor was coldest. Interior had very low humidity. Hallway temperature about 74°F with heated make-up air pumped in at either end. Make-up air thermostat set on "high"; air handlers run during day while maintenance staff present. Interior apartment thermostats are "Comfort Zone" type. Apartment temperatures range from 75°F to 80°F. Some heaters appear to stay on regardless of thermostat setting.

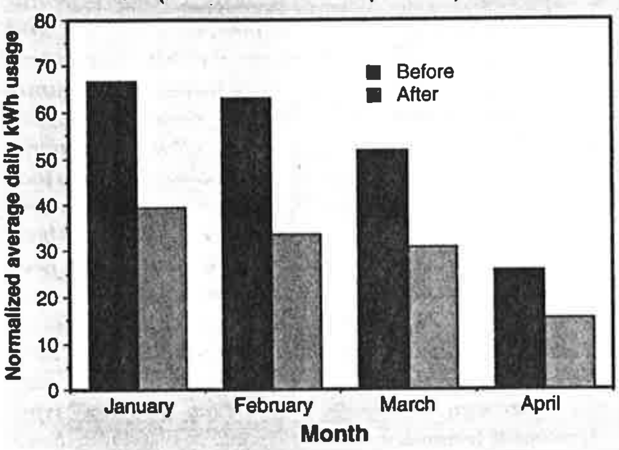
November 26, 1991 (Audit day two, field notes): Investigation of the attic areas on each floor revealed apartment ceilings were sheetrock suspended with a heavy gauge wire from old ceiling 3 ft above in floors 1–3, and 6 ft above on fourth floor. Original brick walls insulated using friction-fit R-19 fiberglass; some has fallen down. In fourth floor cavity, old brick walls missing mortar in many places, and 60% of fiberglass has fallen. Fiberglass still in place has become blackened from air movement. Brick-wall-to-roof junction has a crack about ½–1 in. wide. No insulation on sheetrock below. As per infrared scan, when ventilation system is on, fourth floor cavity depressurizes and cold air



Rick Stover

Thermostat accessibility: another element of successful retrofitting.

Figure 2. Steinhorst Square Apartment Fuel Use
(Fourth Floor Center Apartment)



is pulled in. Attic cavity temperature was 61.8°F, exterior temperature was 26°F.

Hot water flows tested. Showerheads were at 3–4 gpm [gallons per minute] and kitchen faucets at 2.5–3 gpm. Water temperatures ranged from 130°F to 160°F. Water heaters located in apartment closets were uninsulated with unwrapped pipes.

Deciding on the Measures

Once enough data has been collected from site visits, the next step is to put together a picture of the building performance and fuel use, based on analysis of systematically gathered measurements and visual observations. Once these conclusions are drawn, the calculation of savings begins.

This can be done by hand, but is more often done using software that will construct a model of the building using the auditor's observations. In theory, if all of the auditor's observations are correct, the computer model will "use" the same amount of fuel as the real building. Unfortunately, there are many "guesstimates" involved in modeling:

- An accurate assessment of whole building air leakage cannot be determined by testing single units. Some of the "leakage" induced by a blower door test will be air from adjacent units rather than the exterior; how much depends on how well connected they are.
- The computer model requires "hard" data about R-values and wall construction. But it's difficult to quantify the R-value of badly installed insulation or the average temperature in a unit with a bad thermostat.
- The algorithms developed for modelling software are based on laboratory conditions and on building components which are performing perfectly, not the real world performance.
- In an all-electric building, virtually all the electric appliances use electric resistance, providing internal gains from the same energy source used to heat the building.

The post-retrofit model must take the loss of these heat gains into account when figuring payback on measures. For instance, when one upgrades to fluorescent lighting, one loses the waste heat from the incandescent bulb.

December 5, 1991 (Assessing the measures): Further fuel analysis showed heating load portion of fuel bills to be 75% versus 25% for baseload. Potential savings were estimated at 5.3 kWh per ft² per year, or 35%.

Auditor's conclusions:

Problem: *Existing thermostatic controls can best be described as useless. Deadband range was impossible to measure due to the non-calibrated thermostat. Tenant attempts to set back thermostats failed, short of turning the thermostat completely off.*

Solution: *Replace all thermostats with a calibrated thermostat having a 3°F deadband range. Replace living room thermostats with automatic night set-back thermostats.*

Problem: *Exhaust ventilation system overutilized and not balanced by the hallway make-up air. Unheated make-up air is entering the building wherever it can.*

Solution: *Install individually controlled exhaust fans with dampers to code in each kitchen and bath. Vent exhaust air into the old central exhaust ducting.*

Problem: *According to the building plans, the attic cavity walls should be performing at R-14, the roof system at R-13. Actual performance of the walls is R-3 and the roof is R-4. Performance of this cavity shell must be improved.*

Considerations: *If top of drywall ceiling is insulated, attic cavity temperature could drop enough to cause supply water and domestic hot water lines located in the cavity to freeze.*

Solution: *Brace the drywall ceilings and use wet-spray cellulose with a latex adhesive to insulate and air seal the attic cavity. (This retains enough heat within the attic to avoid freezing pipes.)*

SyrEsco

Dirty fiberglass insulation is one sign of air movement within the building cavity. With poorly sealed structures, a large volume of air moves through the insulation, leaving behind smudges of dirt.

Problem: *Domestic hot water tanks and pipes are experiencing heat loss due to lack of insulation. The flows at the kitchen and showers could be moderated.*

Solution: *Install hot water tank wrap and insulate domestic hot water pipes. Install low-flow devices at the kitchen faucet and showerhead.*

__Problem:__ Tenants have a desire to save energy, but need help in directing their efforts into behavior which will save the most energy. In order to make the new measures acceptable and operable, extensive interaction and information must be provided to tenants, building management, and maintenance personnel, too.

__Solution:__ Provide tenant and building personnel education. Provide for ongoing education for incoming tenants and building personnel.

Other measures considered:

__Air Sealing apartments:__ Existing air change rates were very low, and ventilation modifications may decrease those further. No air sealing should be done within the apartment.

__Lighting:__ Heated area lighting changeouts would have a payback of 23 years due to loss of internal gain during the heating season and is not cost effective. Existing exterior lighting is already energy efficient.

After the Installation

Once the audit is completed, the most important step takes place—actual installation of the recommended conservation measures. If the quality of the retrofit was poor, savings will drop from the levels expected from the audit. In general, post-retrofit evaluation of savings is necessary to track building performance. This information can then be used to create a database of actual savings for measures, which will be a more reliable tool for the auditor than savings estimates.

February 10, 1992 (Post-installation notes): Installation began December 9, 1991. It continued through January of 1992. The ventilation system was retrofitted. The wet-spray cellulose was then installed during the holiday season, with temperatures hovering around 0°F. DHW [Domestic Hot Water] measures and thermostat replacements were implemented. On-site supervision was maintained to ensure the quality of the work. The tenants and management were extraordinarily cooperative. Some problems were encountered when it was discovered that those heaters in the corner apartments were wired so that the heaters stayed on regardless of thermostatic control. A change order was issued, and the wiring was repaired.

February 28, 1992 (Evaluation notes): It is important to learn from successes and failures, and this success has taught us a great deal. Every time we go to this building to read meters or inspect something, the tenants come out and comment on their savings. The building owner and the management have experienced savings, as well. We have achieved our goal and made an electrically heated building affordable to tenants on fixed incomes.

Recommendations

In all-electric multifamily buildings, the high cost of fuel makes savings more lucrative. Conservation opportunities are not easy to locate or install. But a meticulous, attentive, and thorough audit will find remedies that will yield the most cost-effective and persistent savings. (See "Retrofit Experience in U.S. Multifamily Buildings," *HE* Mar/Apr '89, p.16.) Such an audit would:

- check the building plans,
- focus air sealing on bypasses—especially between old and new building envelopes—and ventilation systems,
- recommend setback thermostats that are accessible,
- deal directly with the building owner while respecting the interests of tenants,
- generate computer models that take into account other electric uses and heat gains from them,
- look for shortcuts in original construction like miswired appliances and fallen insulation, and
- ensure the quality of work—and savings—by supervising retrofit work. ■