DEVELOPMENT OF A COMPUTERIZED MULTIFAMILY AUDIT: TECHNICAL AND IMPLEMENTATION ISSUES

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ABSTRACT

This paper describes the development of a computerized multifamily energy audit for the Chicago Energy Savers Fund (CESF), an energy conservation program recently initiated in Chicago. The CESF has committed $10 million in low-interest loans to finance energy conservation retrofits in low-moderate income neighborhoods. Since the programs beginning in 1984, over 200 buildings have received program services, including a computerized interactive energy audit, preparation of specifications for proposed work, bid management, construction management, and performance monitoring, depending on their level of progress.

The CNT audit is important because it provides a low-cost tool for accurately estimating savings for the installation of energy conservation measures; thereby, making energy conservation accessible in low-moderate income neighborhoods. The paper describes the steps involved in calculating savings for the installation of energy conservation measures (ECM's). The various components of the audit are: utility bill analysis, building description, BIN method heat load model for simulation of energy consumption, savings calculations of non-interacted and interacted ECM's, and life-cycle costing methodolgy. Particularly of interest are the methods used for determining seasonal efficiency and changes in infiltration.

The paper also describes experience in training auditors from a variety of backgrounds to work in the 8 community based organizations; preliminaty post-retrofit data which shows actual savings ranging from 20 - 50%; modifications and additions which have been made as a result of this experience; further development issues; and relevance of this experience to other localities.

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INTRODUCTION

This paper describes the development of the computerized multifamily energy audit currently being used by the Chicago Energy Savers Fund (CESF), a program designed to reduce energy costs in low-moderate income neighborhoods in Chicago. The CESF has committed $10 millon in low-interest loan funds to finance energy conservation energy retrofits in qualified apartment buildings located in low to moderate income neighborhoods in the city of Chicago. From the program's beginning in October of 1984 to May of 1986, 219 buildings have received program services, including a computerized interactive energy audit, preparation of specifications for proposed work, management of a competetive bid process, construction management assistance, and performance monitoring, depending on their level of progress.

The CNT audit is important because it provides a low-cost tool for accurately estimating savings for the installation of energy conservation measures in multifamily buildings. The multifamily housing stock represents 42% of the total housing units in Chicago, with a majority of these units in low-moderate income neighborhoods. (Michael Freedberg et al, 1985) Previously, the analysis of heating loads and building losses required an engineer, making the technical costs too high to justify an energy audit. The CNT audit provides a tool that can be used by a trained technician to accurately predict savings at a low cost to the building owner thereby making energy conservation accessible in low-moderate income areas of the city.

Because little research has been done on ECM's for multifamily buildings, many of the algorithms for estimating energy savings had to be developed by CNT staff. CNT engineers used the experience gained in the Multifamily Energy Conservation Program (MECP). This program gave CNT engineers a great deal of hands on experience installing and monitoring energy conservation measures. The program involved 346 units of housing in 18 multifamily buildings, and a retrofit cost of approximately $560,000. The MECP experience, a thorough review of the literature and of other audit programs were all used in developing the CNT multifamily audit.

The fact that Chicago has a fairly homogenous housing stock allows us to develop a standardized audit. The typical building is a three story walk-up masonry structure with a flat roof and is approximately 60 years old. Most of these buildings have single pipe steam space heating system with the original cast-iron radiators and either the original coal-fired steel fire-tube boiler that has since been converted to gas or a relatively new cast-iron atmospheric boiler. Some percentage of the larger buildings (greater than 50 units) have two-pipe steam systems. The most common layouts of these buildings are rectangular, L-shaped or U-shaped courtyard buildings.

The paper presents a summary of the steps involved in calculating savings for the installation of energy conservation measures in multifamily buildings.

AUDIT DESCRIPTION

The audit program can be run on any IBM compatible machine including portable machines. This allows for both on-site and off-site processing. CESF elected to process information off-site to minimize the time required of the building owner during the initial site visit. The computer program is user friendly. It is written in a series of imbedded menus which clearly outline the necessary steps. In addition, error messages that display acceptable ranges eliminate extreme errors in data input.

CESF auditors have found the program easy to use, and have mastered all parts of the program in a relatively short time frame. The auditors come from a variety of backgrounds, including roofing and HVAC contractors, members of existing community housing and weatherization programs and engineering. The auditors go through a 8-week training course which familiarizes them with the theory, field work and data collection, the use of the computer program, the potential energy conservation measures, specification writing, and construction requirements. After the completion of the training course the auditors are involved in an apprenticeship period. During this period, each auditor performs audits with varying levels of assistance from CNT depending on each auditor's need. All technical work is monitored by CNT. Most of the auditors work out of the eight housing-related community based orgainizations (CBO) located in the neighborhoods targeted by the program. In addition to providing a built-in capacity within the CBO, the computerized energy audit has added to the capacity of the CBO's to provide fast and accurate responses to many of the vital housing needs in their communities.

The computerized audit has been written in a modular form and can be broken down into the following six steps: 1) Utility Bill Analysis, 2)Building Characteristics, 3)Simulation of Energy Consumption, 4)Non-Interacted Savings, 5)Interacted Savings, and 6)Life Cycle Costing.

Step 1: Utility Bill Analysis

The first step registers actual building consumption which will later be compared with the simulated building consumption. CESF receives utility bills directly from the gas company for each building in the program. Domestic hot water consumption is separated from space heating consumption by estimating the base rate (non-space heating) of consumption. The base rate is found by averaging gas consumption in the non-heating season. The space heating consumption is then normalized for the average Chicago winter and used to determine a space heating index in units of therms/heated sq.ft/year. The space heating index is used to compare buildings to the general Chicago housing stock. The average space heating index for buildings entering the program is 1.14 therms/heated sq.ft/year.

Step 2: Building Characteristics

At this point, building characteristics that will be used in the building simulation module are entered into the computer. These inputs fall into two categories. One type of input is the numbers which are inputed by the auditor, for example heated floor area, or height of the building faces.

The other type of input is a code. The computer then assigns the appropriate value from an existing look-up table. For instance, the auditor will input a code of 1,2 or 3 to distinguish between single, thermopane and triple pane windows. This code will assign the appropriate U-value to each of the windows. In another example the auditor will input the distribution medium type code of 1 to signify steam as the medium of heat distribution; the computer will then look up the appropriate efficiency value for steam as a heat conductor - in this case 1.00. This method of assigning codes rather than having the auditor compute efficiency values both reduces time of calculations and allows auditors with varying backgrounds to accurately calculate savings. The list of the necessary building characteristics can be found in appendix A. Each input is desiginated as auditor calculated input (AC) or look-up table input based on auditor code (LUT) (ASHRAE, Chapter 23, 1981).

Step 3: Simulation

During this module of the program, the information entered in step 2 is used to simulate building energy consumption. This simulated space heating consumption is then compared with the actual consumption that was calculated in step 1 of the audit to determine the simulation accuracy:

$$\text{Simulation Accuracy} = \frac{\text{Simulated Space Heating Consumption}}{\text{Actual Space Heating Consumption}}$$

Simulated building consumption is calculated using the BIN method. The bin method groups outside air temperatures into twenty BINs ranging from -18 degrees to +77 degrees Farenheit. The number of hours that the outside temperature falls into each BIN are summed. Heat loads are then determined for each BIN. Total energy consumption is the sum of the energy consumptions of each BIN.

If the simulation accuracy is not in the acceptable range (95% to 105%), then the auditor begins the process of tuning simulation accuracy. The process entails changing building characteristic inputs which are auditor judgement calls. The following is a list of inputs which can be used in the tuning process: indoor maximum temperature, indoor minimum temperature, setback temperature, spacial weighting factor, degree of balance code, heat gain - cooking, heat gain - electric, and base rate (if estimated because of estimated summer gas bills). These inputs can only be changed if they are auditor estimated values. During the simulation process the heat losses and gains are printed on the screen. The auditors have been trained to identify extreme values and the appropriate inputs to vary. No other inputs may be changed. (Note: None of the following steps can be taken until the auditor has achieved the acceptable simulation accuracy.) The methods for calculating heat loads and building losses at each temperature bin are described in the following sections:

Heat Conduction Losses: Heat loss for the building envelope is calculated using the standard conduction heat loss equations to calculate transmission losses. U-values are stored in look-up tables. The values are assigned based on the auditor inputed description of the building envelope. For example, the auditor inputs the area of the windows and the code for single pane glass and the computer looks-up the appropriate U-value.

Infiltration Losses. One of the unique sections of the audit is the method used to determine building infiltration losses. Specifically of interest is the method used to calculate changes in air flow resulting from the installation of ECM's; this method is described in the non-interacted savings section. The pre-retrofit infiltration losses are calculated using the following formula:

$$Q = CFM * [(Tad - Tbin) * DHRS + (Tan - Tbin) * NHRS)]$$

where:

CFM = Air changes in ft^3/min
Tad = Average Daytime Temperature
Tan = Average Nightime Temperature
Tbin = Temperature of BIN
DHRS = Daytime hours at BIN
NHRS = Nightime hours at BIN

CFM is calculated in the following manner:

$$CFM = AC * HA * GV/HV * CH * 0.018 \ [ft^3/min]$$

where:

AC = Air Changes. The default value is 0.65. This value can be altered by the auditor. Acceptable values range from 0.4 to 0.9 Acceptable values are based on CNT experience and on the experience of the Center for Energy and Environmental Studies (Dutt,et al, 1982).
HA = Heated Area
GV/HV = Gross volume to heated volume
CH = Floor to Ceiling Height

Internal Gains. Internal gains from lights, cooking and appliances are also calculated for each temperature BIN. Each of these calculations is based on actual cooking and electricity bills. In approximately 90% of the buildings, cooking gas and electricity are individually metered. These bills are obtained from the utility companies and used to calculate the cooking gas and electricity costs per apartment. In cases where the building is master metered, the auditor makes assumptions based on occupancy using previously gathered data on cooking and electricity costs.

Solar Gains. Solar gains are calculated assuming a straight line function of solar gain versus outdoor temperature. Summer and winter design values have been calculated at January 21 and July 21. These design values are used as endpoints of the straight line function. Solar gain is calculated for each building face and type of window independently using the standard ASHRAE method. The procedure is as follows: 1) Determine total window area for each window type for each building face, 2) Determine fraction of window area that is shaded for each window type for each face, 3) Look-up cooling load factor (ECLF) for each face. Values used are looked-up and depend upon face orientation (ie, North, South, East, West), 4) Look-up solar heat gain factor (SHGF) for each face. These values also depend on orientation of face, 5) For each window type, look-up shading coefficient, 6) Calculate the January and July gains for each window type,

7) Repeat steps 2 - 6 for each window type on each face, 8) Sum gains for each face for July and January, 9) Sum gains for all building faces for July and January, 10) Determine solar gains for skylights in similar manner as described in steps 1 - 6 for windows, 11) Sum total building gain for January and July. (Note: All above look-up values come from Medium Construction ASHRAE Chapter 26 Table 13.)

Calculation of Simulated Space Heating Consumption. Each component, gains and losses, are summed at each temperature BIN to determine the net energy required. Heating is required anytime the net energy requirement is negative. The net required energy is then used with the seasonal efficiency at each BIN to calculate heating energy input for that BIN.

Seasonal Efficiency. Seasonal efficiency is different from combustion or steady-state efficiency because it takes into account total building heating system losses. Seasonal efficiency is calculated by summing part-load efficiencies determined at each temperature BIN (over the whole season). Part load efficiency is defined as:

$$\text{Partload Efficiency} = (SSE - JLE) * (CE)*(DE)*(BCE)$$

$$\text{And: } DE = (DME)*(TE)*(PIE)$$

where:

SE = Steady State Efficiency is calculated from the field measured flue gas temperatures and CO_2 percentage in flue gases(Dyer et al, 1980)

JLE = Loss in Steady State Efficiency Due to Jacket Losses.(Weil McClain, 1981) Values are looked-up based on the jacket insulation code and type of heating plant.

CE = Cycle Efficiency is a function of percent on time, which is calculated from the auditor-inputed measured firing rate, and changes for each temperature BIN. (Weil McClain, 1981)

DE = Distribution Efficiency is a calculated term which takes into account losses due to inefficiencies in the distribution system. Auditor inputs are spatial weighting factor and degree of balance.

DME = Distribution Medium Efficiency is the efficiency of the distribution medium to conduct heat to the conditioned space and is based on the auditor inputed type of distribution medium.

TE = Efficiency of Radiation Type which is calculated by dividing the rated capacity of the terminal units at design conditions divided by the actual output from the boiler. This efficiency is based on auditor inputed terminal unit type.

PIE = Pipe Insulation Efficiency allows for heat losses through pipe insulation and is assigned a value based on auditor inputed desription of pipe insulation level and location. Heat losses through pipes with varying insulation levels were calculated using heat conduction equations by CNT engineers.

BCE = Burner Control Efficiency is an efficiency which is determined depending on the type of burner controls. These efficiencies are calculated based on overheating and short-cycling losses that are due to inefficient boiler controls. For example, in the typical poorly balanced building, many of the apartments will be at a higher temperature than the minimum required temperature.

The overheating can be converted into a measure of inefficiency by multiplying the difference between the effective average temperature due to the control temperature and the minimum required temperature by the percent change in building energy consumption per one ^{O}F change in indoor average temperature. The auditor inputs to this inefficiency are degree of balance, spatial weighting factor, minimum & maximum indoor temperatures, and the burner control code.

The seasonal efficiency definition used in the CNT audit has several advantages. Firstly, it allows a complete accounting of the inefficiencies of converting the energy contained in the fuel delivered to the burner into thermal energy in the conditioned space. It addresses each component of the heating system: heating plant, distribution system, terminal units and controls. Secondly, the efficiency description includes a measure of comfort -- required minimum indoor temperature. The minimum temperature is an indicator of the required heat to maintain a minimum comfort level. In addition, the seasonal efficiency is convenient for determining the source and magnitude of inefficiencies in the heating system. Once the heat loss characteristics have been specified, this minimum heat requirement can be described in terms of the required minimum and uniform indoor temperature. The uniform indoor temperature refers to temporally and spatially constant indoor temperature; therefore allowing a quantification of minimum heat requirements and inefficiencies. (Note: more detailed information on the heating system efficiency model can be found in Katrakis et al, 1985.) An average seasonal efficiency for the Chicago multifamily building stock is 50% based on 25 buildings audited by the Center for Neighborhood Technology.

The net energy required is divided by the seasonal efficiency at each BIN to determine the heating energy input. The heating energy input is set to zero when the net required energy is positive. The total predicted heating consumption for the year is the sum of the heating energy inputs at each BIN.

This calculated total predicted heating consumption is the simulated consumption that is compared with actual space heating consumption to determine the simulation accuracy, as described in the simulation section.

Step 4: Calculating Savings for Non-interacted ECM's

The list of ECM's that can be analyzed by the computer program and considered for funding by the Chicago Energy Savers Fund was developed by the Illinois Commerce Commission (ICC), the regulating organization of the Chicago Energy Savers Fund. The list was developed based on input from CNT based on experience gained in the pilot program, the Multifamily Energy Conservation Program (MECP) and experience gained in other cities. The MECP experience was found to be very valuable in choosing cost-effective energy conservation measures to be considered in the CESF program. The complete list of ECM's can be found in Appendix B.

Savings are calculated for non-interacted energy conservation by re-simulating the existing building with the addition of the new energy conservation measure. The method described in the previous section is used when recalculating the space heating consumption required for the new simulation. The following two sections are examples of savings calculations from the installation of ECM's affecting seasonal efficiency and infiltration.

Seasonal Efficiency ECM Calculations. The installation of a new boiler affectively improves the building efficiency by improving the steady state efficiency, the jacket losses and the cycle efficiency. The example suggested is replacing a 60 year old steel brickset boiler with a power burner with a new cast iron boiler also with a power burner. Table I shows the changes in the efficiencies listed above and the resulting savings.

Table I. Savings Calculations for New Boiler

	Existing Boiler	Cast Iron Power Burner
Steady State Efficiency	0.74	0.80
Jacket Losses	0.04	0.02
Cycle Efficiency (Average)*	0.84	0.86
Distribution Efficiency**	0.87	0.87
Burner Control Efficiency	0.77	0.77
Building Efficiency	0.40	0.45
Heat Load (MBTU/Hr)	553.54	553.54
Energy Required (MBTU/Hr)	1421.47	1221.82
Savings ($/Yr)	$0.00	$1157.97

*Cycle Efficiency is dependent on percent on time of the boiler. The value is different for each temperature BIN.

**Distribution Efficiency Components: DME = 1.00, TE = 0.92, PIE = 0.95

Infiltration ECM Savings. At the time of audit development, an appropriate infiltration air path model was not found for the multifamily building stock in Chicago. The CNT staff, therefore, incorporated existing information on single family buildings to determine a method for calculating changes in air flow and for attributing savings to infiltration related ECM's. The method used is a resistance model for calculating effective total leakage area. The approach taken is as follows:

1. Calculate leakage area of windows using the resistance model. See Figure 1 below:

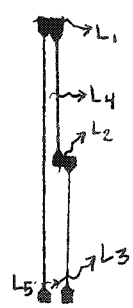

Figure 1. Schematic of Infiltration Resistance Model for Windows where total prime window leakage area is (components in parallel):

$$Lp = L1 + L2 + L3 + L4$$

where:

L1 = Perimeter leakage
L2 = Meeting rail leakage
L3 = Putty Leakage
L4 = Cracked or broken glass leakage
L5 = Storm window leakage

Total Window Leakage Area (LW) considering both prime and storm window (prime and storm components in series) is:

$$LW = \frac{1}{[(1/Lp)^2 + (1/L5)^2]^2}$$

Window leakage is calculated from look-up values based on an auditor judgement of parameters such as window tightness and condition of weatherstripping. The window leakage equations are:

$$L1 = (WW + WH) * WIS$$
$$L2 = (WW) * WIR$$
$$L3 = 2 * (WW + WH) * WI$$
$$L4 = 2 * (WW + WH) * WI$$
$$L5 = 2 * (WW + WH) * WI$$

where:

WW = Window Width
WH = Window Height
WI = Window Infiltration (in area/ft perimeter). Values are looked-up in tables and depend on auditor inputed desription of windows (ie, window tightness, window condition, etc.)
WIS = Window Sash Infiltration (in ft^2 area/ ft perimeter)
WIR = Window Meeting Rail Infiltration (in ft^2 area/ft perimeter)
Note: Reference for values is Ashrae, Chapter 23, 1981.

2. Calculate the Total Effective Leakage Area of the building.
A similar method was developed to determine effective leakage area of all bypasses including all wall bypasses, partition wall bypasses, attic insulation per apartment, stack bypasses, ceiling penetrations per apartment stack, leakages through furring space per floor per face, ceiling wall crack, etc...However, it became apparent that data was not available for most of theabove listed proposed leakage areas. For this reason, the Total Effective Leakage Area for the building (TLA) was estimated based on the other infiltration sources to be a given percent of the total window leakage area (LW). Specifically, each individual component, including bypass infiltration, wall infiltration, and remaining infiltration components, are estimated as being a percentage of the window infiltration. These percentages are based on relative crack lengths, CNT experience and single family data. All infiltration sources are considered as parallel components responding to the pressure difference between the outside and inside of the building.
3. Calculate the differential pressure between inside and outside.
Once the total effective leakage area of the building is known, the pressure difference between the inside and outside of the building can be calculated from the following formula:

$$P = \frac{(CFM / TLA)^2}{2*G/(DA*PCF)} \quad \text{(Sherman et al, 1980)}$$

where:

CFM = Total Infiltration
TLA = Total Effective Leakage Area
G = Gravitational Constant
DA = Density of Air
PCF = Pressure Conversion Factor

4. Determine reduction in leakage area caused by ECM and recompute the CFM. The pressure is assumed to stay constant. The installation of infiltration related ECM's changes the effective leakage area. For example, the installation of storm windows changes the effective leakage area of the windows. The above equation is then used to calculate the new total infiltration value, CFM.

Step 5: Interacted Savings

Interacted savings are calculated by re-simulating building energy requirement for each succesive energy conservation measure. ECM's are listed in order of cost effectiveness. Cost effectiveness is determined by the Benefit to Cost Ratio (BCR) which is described in the following section; Life-Cycle Costing. The most cost-effective ECM is processed first, thus establishing a new baseline building consumption. The second most cost effective ECM is then processed to establish the next baseline. This process is continued until all the selected ECM's have been used to calculate the final building consumption. The order generated during the non-interacted ECM process is used as the order that each ECM is added to the existing baseline. This final building consumption is compared to the pre-retrofit building consumption to calculate savings. Table II shows both the non-interacted and interacted savings for the selected package of ECM's.

Table II. Non-Interacted vs Interacted Savings

	Non-interacted				Interacted		
ECM Description	ECM$	O&M$	FYS	YRS	FYS	YRS	BCR
Outdoor Temperature Cutoff	1500	0	411	0.37	411	0.37	27.38
Turbulators	600	0	638	0.94	604	0.99	20.12
Install New Tank Type Heater	3380	0	2024	1.67	2024	1.67	4.79
Replace Line and Radiator Vents	350	0	288	1.22	261	1.34	3.72
Light Fixture Replacement	1080	0	288	3.74	288	3.74	4.01
Ceiling Cavity Insulation	4935	0	641	7.69	574	8.60	3.49
Indoor Thermostat	1798	0	676	2.66	229	7.86	1.27
Top-Side By-Pass Sealing	1200	0	382	3.14	333	3.61	2.77
Exterior Storm Windows	8060	0	1927	4.18	1599	5.04	1.98
Clean & Tune Boiler	4500	0	430	10.48	280	16.08	0.31

where:

ECM$ = Cost of Energy Conservation Measure
FYS = First Year Savings in $
O&M$ = Cost of Operation and Maintenance
BCR = Benefit-to-Cost Ratio (defined in the following section)

Step 6: Life-Cycle Costing

Although life-cycle costing is listed as the final step of the computerized audit process, it is used in both steps 3 & 4. The life-cycle costing term used is the Benefit-to Cost Ratio (BCR). The BCR algorithm takes into account first year savings, projected life-time, initial investment, and maintenance costs. The algorithm is:

$$BCR = \frac{PWES - PWOM}{CST}$$

where:

PWES = Present worth of estimated savings
PWOM = Present worth of Operation and Maintenance
CST = Current cost of ECM

This approach weights the BCR by lifetime and allows the auditor and owner to take this factor into account. CESF can only fund a package with a BCR of greater than 1. This restriction limits the amount of non-energy or deferred maintenance that the program can fund. The average BCR for approved loans is 2.3.

The terms of the loan agreement are over a ten year period with 7% interest. The total loan amount does not include the total costs for adminstering the program. This cost is heavily subsidized by the Chicago Energy Savers Fund. To date no loans have been defaulted.

CONCLUSION

Results of a preliminary analysis of the performance of post-retrofit buildings are encouraging. Because the Chicago Energy Savers Fund is still in the beginning stages and there is a lag time in release of utility bills to CNT, only limited post-retrofit utility data is available. Also, because the utility company uses a system of estimating bills, post-retrofit performance monitoring has been delayed by the necessity of having analysis periods that begin and end with actual meter readings. These reasons account for the limited list of post-retrofit data that follows below:

Table III. Energy Savings in CESF Multifamily Buildings

	Number of Units	Actual	Predicted
B841001	11	26%	20%
O841002	15	40%	33%
O851003	11	21%	15%
P851006	47	50%	39%
C841001	7	36%	28%
C851005	8	34%	40%
B851003	6	25%	28%

(Note: This data is preliminary and was calculated based on 3 to 7 months of data.)

Actual savings were calculated based on pre-retrofit and post-retrofit utility data that begins and ends with actual meter readings. The data was normalized for the average Chicago winter. All of the above retrofits included both mechanical and envelope work. The typical retrofit is: ceiling cavity insulation, top-side by-pass sealing, exterior storm windows, replacement of main line and radiator vents (balancing the heating distribution system), space heating boiler flue dampers, indoor thermostat, outdoor temperature cutoff, clean & tune boiler, domestic hot water flue damper, fluorescent lighting fixtures and photoelectric lighting control. Retrofit costs ranged from $ 4,011 - $ 24,000. Based on these preliminary results, the program has been successful in saving energy. It has proven that building management has a large effect on actually achieving savings. We are continually working with owners and building managers to ensure energy savings.

The Chicago Energy Savers Fund has gained a great deal of experience from the over 200 buildings that have been involved in the program since its beginning. As a result of this experience, CNT has made minor modifications to the audit. Modifications to the program include changes in burner control efficiency and degree of balance efficiency based on the availability of more accurate data; the ability to account for bypass losses through attic insulation; and the ability to handle individual space heated buildings with five types of individual heaters. CNT has also identified areas of necessary research, some of which we are currently conducting. Specifically, we would like to expand the infiltration module to incorporate the resistance model for all leakage areas. This would require obtaining infiltration data for sources other than window leakage. In addition, we are currently doing research with GRI on the space heating seasonal efficiency.

The experience of the Chicago Energy Savers Fund is relevant to many other locales - particularly the older cities of the northeast and midwest which have similar housing stocks and similar climates. The computerized audit, however, is not limited to the building or climate charactersitics of these areas since it is written in a series of modules that can be easily modified as necessary. In order to accurately modify the audit program for other cities, preliminary reserach on both the housing sotock and appropriate energy conservation measures would have to be performed. A high degree of technical experience is not required to operate the audit. This allows auditors from a variety of backgrounds to be trained in a relatively short time. The auditors work out of their community based organizations which makes them accessible to the building owners. Consistent contact from the technician ensures a more active participation of building owners and managers and an increasing neighborhood sensitivity to the issue of energy conservation. The multifamily audit program has successfully provided an easy-to-use tool which makes energy conservation accessible in low-moderate income neighborhoods.

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Appendix A
Multifamily Energy Audit Input Checklist

Input Type	Field Name	Range	Description
AC	Total units	1-200	Total apartment units in building
AC	Indoor daytime min temp	50-90	Temperature in degree Farenheit
AC	Indoor daytime max temp	50-90	Temperature in degree Farenheit
AC	Spacial weightng factor	0-9	0 weights towards min temperature 9 weights towards max temperature
LUT	Radiation - Hot/Warm/Cold	1,2,3	1- Hot, 2-Warm, 3-Cold
AC	Setback temperature	50-90	Night time setback temperature
AC	Corner	N,O,I,E	N for North start direction, O-outside corner, I- inside corner, E- End of building description
AC	Distance		Face length in Feet
AC	Total heated Flr. Area		Heated floor area in ft^2
LUT	Wall construction	1,2,3,4	1- 12"brick on lath, 2- 8" brick -plaster on lath,3-12" brick no interior finish, 4-8"brick- no interior finish
LUT	Wall Insulation	1-6	Insulation levels from none-R20
LUT	Exterior Solar Shading	0-9	Exterior Solar Shading Factor used to calculate Solar gains.
AC	Height of face above grade		Height of face in feet
AC	Window Width		In inches
AC	Window Height		In inches
LUT	Window Code	1-9	Window description codes signify wood double hung, wood casement, wood fixed, metal casement, metal horiz sliders, metal fixed, alum double hung, glass block
LUT	Prime glazing	1-3	Code signifies single, thermopane or triple
LUT	Window Covering	1,6	Code signifies covering types from none, rooler shade, interior plastic, thermal shade R4, Thermal shade R7, Plywood
LUT	Storm Window	0-2	Code signifies, none, exterior triple track and interior
LUT	Window Tightness	1-3	Code signifies tight, medium or loose
LUT	Weatherstripping	1-3	Good, Fair, Poor
LUT	Window Location	1-3	Heated Area, Common Area, Unheated Area
AC	Window Quantity		Quantity
AC	Door Width		In inches
AC	Door Height		In inches
LUT	Door Code	1-5	Solid Wood, 50% Glass, Ft. Entrance 50-100% Glass, Metal uninsulated, metal insulated core
LUT	Door Covering	1-4	None, metal storm door, wood storm door, enclosed vestibule or porch
LUT	Door Location	1-3	Heated Area, CommonArea, Unheated Area
AC	Door Quantity		Number

Appendix A (cont)

LUT	Roof Code	1-2	Wood roof w/attic space pre 1940 Wood roof w/attic space post1940
AC	Area of roof section		In feet
LUT	Roof insulation	1-5	None, R&, R11, R19, R30
AC	Skylight Width		In inches
AC	Skylight Length		In inches
AC	Skylight Quantity		Number
LUT	Skylight Type	1-2	Single or double glazing
LUT	Skylight venting	1-3	None, single stack, double stack
AC	Height above grade		In feet
AC	Height below grade		In feet
LUT	Type of heating plant	1-4	Atmospheric, Firetube 1 pass, Firetube 1-2 pass, Sealed combustion
AC	Rated Input in Btu/Hr		In Btu/Hr
AC	Measured Firing Rate		In Btu/Hr
LUT	Type of draft control	1-3	none, thermal flue damper, mechanical flue damper
LUT	Jacket Insulation	1-3	Well insulated, moderate insulation, no insulation
LUT	Burner Control Type	1	Pressuretrol
		2	Pressuretrol, Timeclock
		3	Pressuretrol, timeclock,aquastat, outdoor limit
		4	Steam cycle controller
		5	Indoor Thermostat
AC	Flue Gas Temperature		in ^{o}F
AC	Flue Gas CO^2		in percentage
LUT	Heat Distribution	1-3	One pipe Steam, Two pipe steam, Hot Water
LUT	Degree of Balance code	1	Poor Balance, 8 degree temp diff.
		2	Typical Balance, 6 degree temp diff
		3	Good Balance, 3 degree temp diff
		4	Multizone, 2 degree temp diff
		5	TRV's, 1 degree temp diff
LUT	Distribution Medium	1-2	Steam, Hot Water
LUT	Terminal unit type	1-5	Cast iron uprights, baseboard-alum fin, baseboard - cast iron, hot water radiant floor/ceiling, fan coil units
LUT	Individual Heating codes	0-5	Central heating, forced hot air AFUE .9-.95, Forced hot air AFUE .8-.85, Forced hot air AFUE .65-.7, indiv heater no distribution -blower, indiv heater no distr non blower
LUT	Distr piping insulation	1-3	Well insulated, moderate insulation, none
LUT	Distribution piping loc.	1-3	Conditioned Space, partially heated basement, unheated basement
LUT	Domestic hot water System	1-4	Water-Water heat exchanger, water-steam heat exchanger, standard tank type, boiler-storage tank combination

AC	Storage Tank Capacity		in gallons
LUT	Storage tank insulation	1-4	None, 1" fiberglass=R3,2" fiberglass =R7, 3" fiberglass =R10
LUT	Flue damper	1-3	None,thermal,mechanical
AC	Water temperature	100-180	Temp in Farenheit
AC	Number of showerheads/apt		In quantity
AC	DHW Combustion Efficiency		in percentage
AC	Location code(lighting)	1-5	Exterior security pole,exterior wall,lobby,interior hallway,basement or common area
AC	Number of fixtures		number
AC	Wattage per fixture		wattage
LUT	Type of lamp	1-2	Incandescent or fluorescent
LUT	Type of fixture	1-3	Exterior, enclosed bulb, open bulb
LUT	Control of lighting	1-4	Continuous operation, manual control,clock timer, photocell
AC	Lighting operating hours	0-168	On time of lighting in hours
AC	Cooking Gain		in MMBtu
AC	Electric Gain		in MMBtu

APPENDIX B
Multifamily Energy Conservation Measures

Envelope ECM's:

Exterior Storm Windows	Replacement Windows
Insulating Window Shades	Reflective Window Shades
Ceiling Cavity Insulation	Roof-top Insulation
Storm Doors	Outside Wall Insulation
Inside Wall Insulation	Basement Wall Insulation
Top-Side By-Pass Sealing	Skylight Second Glazing
Masonry Repairs	Window Cauling
Window Weatherstripping	Window Repairs

Heating System ECM's:

Burner Adjustment	Combusiton Air Inlet Damper
Replacement Burner	Clean and Tune Boiler
Install Zone Control	Circulating Pump Controls
Insulate Distribution Piping	Turbulators
Draft Control	Flue Damper
Replacement Boiler	Fuel Conversion
Replace Line and Radiator Vents	Thermostatic Radiator Valves
Replace Steam Traps	Install Vacuum Pump
Indoor Thermostat	Cycling Steam Control
Outdoor Reset Control	Outdoor Temperature Cutoff

DHW ECM's:

Replace Boiler Sidearm Heaters	Install New Tank-Type Heater
Install Storage Tank/Boiler	Recirculating Pump Controls
Flow Restricting Fixtures	Insulate Piping
Insulate Hot Water Tank	Flue Damper

Lighting ECM's:

Control Light Switching	Light Bulb Replacement
Install Fluorescent Fixtures	