Addressing Climate Change by Retrofitting Chicago's Buildings: The Whole Home Energy Savers Experience

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ABSTRACT

This paper will discuss CNT Energy's progress and lessons learned on the Chicagoland Home Energy Savers (CHES) project. This was a pilot program designed to test the viability, methods and costs of delivering 30% savings through weatherization, with combined gas and electric measures and a whole-home systems approach. Installed measures and preliminary savings will be reported. A discussion of the barriers to scaling-up energy efficiency in Chicago with respect to service providers, consumers and program implementers will be included.

The retrofitting of residential buildings has been identified as a substantial opportunity for energy savings in the City of Chicago's Climate Action Plan (CCAP). The Center for Neighborhood Technology (CNT) was instrumental in developing this plan, which proposed building audits and retrofits for 400,000 housing units resulting in 30% savings per home. The CHES pilot program was designed to test bringing retrofits to scale. The project had three goals: a working group to attain consensus on energy retrofit measures and approaches, the auditing and weatherization of 30 housing units, in single and small multifamily buildings with the goal of attaining 30% savings, and the monitoring of these units to determine if the retrofits achieved the energy savings goal.

The CHES pilot addressed questions about the appropriate role of energy audits, the viability of the Home Energy Rating System ratings, how to address Chicago's diverse housing stock, and barriers to effective marketing and delivery of services to the diverse populace. Preliminary results from the program are promising, with an average overall energy savings of 26%.

Introduction

This paper will discuss CNT Energy's progress and lessons learned on the Chicagoland Whole Home Energy Savers project. In 2008, the City of Chicago released a Climate Action Plan (CCAP). The Center for Neighborhood Technology provided the analysis for the baseline greenhouse gas levels, and was instrumental in developing the mitigation and adaptation strategies that could reduce the impacts of climate change. The Plan identified residential building audits and weatherization retrofits as one strategy. The CHES project was designed to test the viability of this idea, using a "whole home" approach and combined gas and electric home energy retrofits. Although 30% savings over 400,000 housing units was postulated as an achievable standard, results from existing weatherization programs have only achieved savings ranging from 13 to 24% (Chicago Department of Environment). The program was designed by a working group of energy efficiency practitioners in the Chicagoland area. The test subjects included a representative sample of typical Chicago housing types, including single and small multifamily buildings, of both frame and masonry constructions. Through the working group and retrofit process, observations on the variety and viability of energy audits, how to address Chicago's diverse housing stock, and barriers to scaling up the residential retrofit market were discovered.

Energy Efficiency Grows in Illinois

The State of Illinois has an abysmal record of investment in energy efficiency, both by the government and large investor–owned utility companies. As Illinois' largest city, Chicago reflects this disinvestment. In 2007, as gas and electric utilities were just unveiling new efficiency portfolios, Illinois ranked last among twenty-eight states with sizeable utility investment. However, this status changed dramatically when in new energy portfolios, Illinois jumped to seventh; representing a spending increase from a fraction of utility revenue to roughly 2%. Naturally, Illinois is experiencing the growing pains to be expected when a marketplace and service industry that has operated on the margins of the economy suddenly must replicate its production many times over and within a short period of time. The current funding and the scale of the CCAP goals are ambitious in light of the many barriers to bring the retrofit market to scale in that were identified in the CHES pilot. These barriers include: an economy that is not encouraging to investment, consumers with little or no disposable income, lack of understanding around energy efficiency investments and a need for more service providers.

The State of Illinois and Peoples Gas[1] proposed and funded the Chicagoland Whole Home Energy Savers pilot. It was conceived to address some of the challenges inherent in the anticipated scale-up process: including identifying and inventorying the type and quality of regional service providers (auditors, contractors) operating in Illinois, determining how cost effective energy efficiency packages can be assembled for architecturally diverse building types, and assessing whether and how the process and implementation of these packages can be scaled up to levels that reach the ambitious goals of the CCAP.

With Old Buildings Comes Great Opportunity

Chicago's housing stock can be characterized by three words: big, old and diverse. There are approximately 600,000 buildings containing about 1,000,000 housing units (i.e., a house or apartment that is intended and equipped for occupancy) in Chicago. Nearly 70% of units are in single family and two to four unit buildings and approximately half of these were built before 1940 (CCAP). In acknowledgement of these factors, the majority of the buildings in the CHES sample group were older residences. The question of how to effectively weatherize this housing stock was the primary one considered by the Whole Home Working Group.

Older buildings were not designed for energy efficiency and are becoming less energy efficient through physical plant deterioration. Energy use in Chicago buildings is responsible for 70% of greenhouse gas (GHG) emissions in Chicago; 50% of those emissions are from energy use in residential buildings. Because 80% of the buildings existing today will be in use in 2020, great potential for GHG emissions reductions exists through building energy efficiency programs.

The CHES Whole Home Working Group

The CHES project included convening a whole home Working Group (WHWG). The WHWG consisted of energy auditors, utility company representative, program implementers, and city and state energy efficiency liaisons, among others. The group was convened to discuss specific audit and retrofit

[1] The People's Gas funds are part of the Enhanced Efficiency program funded by the customers of Peoples Gas and North Shore Gas. The State of Illinois funding came from the Department of Commerce and Economic Opportunity. The Program is guided by Peoples Gas, North Shore Gas, the Citizens Utility Board, the City of Chicago Department of Environment, the Environmental Law and Policy Center and the Illinois Attorney General's Office.

approaches and technical standards, including which specific retrofits measures were appropriate for consideration during the program and what the role of outside energy auditors would be. The WHWG focused on key topics that shaped the pilot program over a series of ten bi-weekly meetings. The topics discussed included the state of energy auditing in Illinois, an analysis of the distinct building types representative of Chicago's housing stock, the identification of the criteria for qualifying homes, and the specific energy efficiency measures (i.e. attic insulation, high efficiency furnace) to be considered in the project.

Project Design

The project's subjects were buildings that were representative of Chicago-area housing stock. The WHWG identified several distinct, typical types of housing for inclusion in the project. In general, there was a distinction between brick and frame homes and single family and two to four unit buildings. A more modern housing type - ranch style homes with no basements were also identified. Table 1 describes the building characteristics of these housing types.

Table 1: Proposed Building Types & Characteristics

Building Type	**Building Characteristics**
Single Family Frame	Often sheathed with aluminum or vinyl siding, frame and sheetrock construction, great opportunities to reduce air leakage and add insulation, often with basements used for storage and/or crawl spaces
Frame Flat	Similar to single family frame with 2-4 units, often with enclosed back porches that are not technically part of the thermal envelope.
Single Family Brick	The classic Chicago bungalow, an Arts and Craft style building. The original structures have often been renovated by non-professionals to increase living space
Brick/Masonry Flat	Brick or greystone walkups. 2-4 flat building masonry walls, typically no wall insulation and small wall cavity making adding insulation impossible. Basement often doubles as storage and mechanical space
Frame & Masonry	Masonry building with elements of frame construction
Ranch on Concrete Slab	Single family frame or brick walled home with no basement, often with attached garage, typical of suburban neighborhoods

Many of Chicago's single family brick homes are bungalows. These masonry structures, built from 1900 to 1940, are home to 80,000 families, of all income levels. Classic bungalows are recognized as historic structures, and as such can receive special financing for restorations. They are so ubiquitous that a special delegate agency, the Historic Chicago Bungalow Association, was established to provide information and technical assistance for homeowners. For this project, the HCBA was funded to administer retrofits on these building types. CNT Energy audited 45 housing units to choose the thirty homes that would be weatherized.

Selection of participants and building types

The buildings included in the study received the services and installation of energy efficiency improvements at no cost – a significant award. Consequently, CNT Energy worked with nonprofit housing groups to identify low to moderate income households to receive this benefit. We could also identify buildings that would provide the best test subjects. Factors used to evaluate the projects included:

- The occupancy of the building is stable
- The thermal barrier is intact – i.e. the occupied area has not extended beyond original structure's layout, or the basement or attic hasn't been remodeled as a second living unit
- The building's residents are receptive to, and ready to be engaged in, energy savings; so behavioral changes can supplement the installed energy conservation measures (ECMs)
- The building's residents pay for their utilities (e.g., tenants where the landlord pays for heat are less likely to be motivated to reduce natural gas usage
- The building has older mechanical systems. Based on the age of the housing stock, it is not unreasonable to assume that this condition can be representative of Chicago's housing stock

Other factors, if present, were grounds for exclusion from the program. These included:

- The building structure, overall, is in a state of disrepair
- The roof is leaking or otherwise not stable
- The building has or is likely to have significant water damage (flooding)
- Conditions that are a threat to health and safety are present. This includes but is not limited to hazardous materials such as lead and asbestos. The presence of old electrical connections (knob and wire) also precludes the addition of insulation
- Utility service has been shut off
- The building is not ready for construction due to excessive clutter
- The building is financially at risk of foreclosure
- The building does not have property insurance

The due diligence of checking property insurance, deed and title of ownership and assessing whether or not the property was in foreclosure was especially important at homes owned by lower income residents.

Pre-audit conditions

CNT selected homes based on the criteria developed by the WHWG and enrolled the following distribution of homes. In total 30 units in 17 buildings were retrofitted.

Ten of 17 buildings were equipped with natural gas furnaces. Three homes had older gas vented space heaters in lieu of, or in addition to, central heating plants. These space heaters were commonly in use in the past, but currently are not allowed by code and represent a safety liability, in addition to low efficiency. Removal of space heaters and installation of gas furnaces and associated duct work was considered a necessary solution to the problem. The removal of space heaters became even more crucial as building envelopes were tightened and air exchange between the indoors and outdoors was reduced. Most homes did not have central condensers as part of their air conditioning system.

The majority of homes had little or no insulation. Several homes had some ceiling insulation, but not to the recommended R-38 and often it was poorly installed and in degraded conditions. Blower door results were often higher than 5,000 CFM50 (cubic feet per minute or 2359 liters per second at 50

Pascals) indicating great potential for reducing air infiltration. In general blower door readings were collected at three times: the initial audit, following insulation/air sealing (by the contractor) and as part of the post-retrofit verification process (by a second energy auditor). Some newer homes had very low air infiltration rates due to tighter construction and more insulation.

The audit and retrofit process

The WHWG reviewed available energy auditor training and determined that certification is not typically required for energy auditors in the private market in Illinois. Further, the type of energy audit can determine the level of training that is necessary. In determining the type of audit necessary for comprehensive home energy audits the WHWG identified three certification programs: RESNET (Residential Energy Services Network) certification of Home Energy Raters, Building Performance Institute (BPI), and IHWAP (IL Home Weatherization Assistance Providers) certification.

RESNET defines three types of energy audits: In-Home Energy Survey, In-Home Diagnostic Energy Survey, and Comprehensive Energy Audit. The WHWG determined that they wanted a "comprehensive" audit for these pilot buildings, and the HERS (Home Energy Rating System) energy raters were contracted for a HERS audit as the standard audit for this program. The HERS audit provides a list of measures and modeled energy savings, data that the WHWG wanted for analysis and scope of work purposes. However, many auditors, including the ones hired for this project, were certified by both RESNET and BPI. Following the installation of efficiency measures, a second energy auditor was retained to conduct an independent post-installation inspection. The following table details the testing and deliverables provided in these audits.

Table 2: Pre and Post Audit Procedures

	Initial Energy Audit	**Post Retrofit Verification**
Type of Audit	Whole house HERS audit with modeling and recommended measures work order provided, Blower door tests, carbon monoxide safety testing: analysis/worst case depressurization, radon testing.	Visual and thermographic inspection of installed measures, verification of post-retrofit blower door tests, carbon monoxide safety testing analysis/worst case depressurization

Project installations

The specific energy efficiency measures that were installed in each housing unit were based on the recommendations, summarized in a work order, from the energy audits performed by third party auditors. The installation packages were budgeted at an average of $10,000. The typical cost of retrofits is $5000 for single family homes. This budget was intentionally set higher, so as not to preclude a comprehensive scope of work. The larger issue of cost-effectiveness from a total resource cost perspective and what type and term of investment the average home owner considers acceptable must be considered in any attempt to scale up the projects.

Figure 1 below indicates that natural gas makes up the large majority of the energy consumed at the properties; all use natural gas for space heat and for domestic hot water. The dominance of gas in the energy use profile encouraged the installation of mainly natural gas saving measures in spite of the project design of utilizing combined gas and electric measures.

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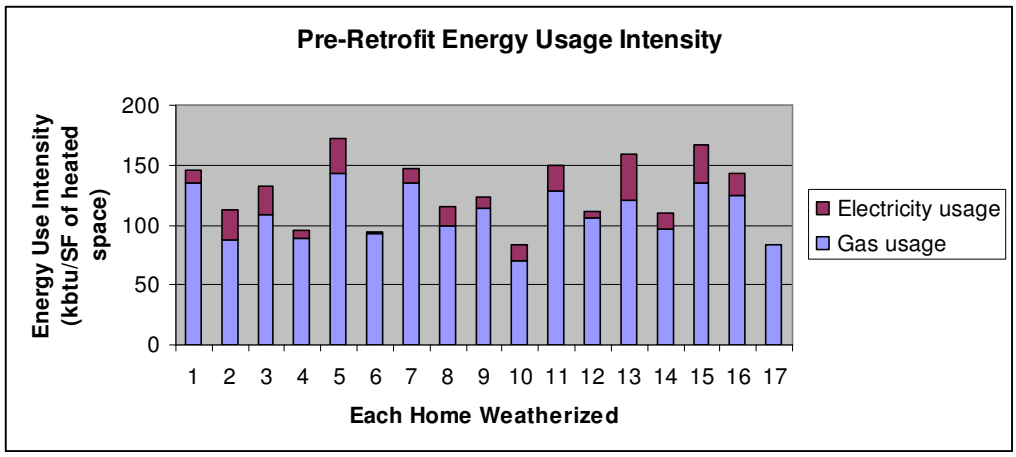

Figure 1. Per Annum Pre-Retrofit Energy Usage Intensity

Figure 2 below shows the frequency with which certain efficiency measures were installed. Insulation and air sealing were the most common occurring in every scope of work. Heating system upgrades including furnace replacement and removal of gas space heaters were also common. Low cost items were installed in every home including high efficiency light bulbs, low flow shower heads, carbon monoxide detectors, smoke alarms, and insulation around exposed domestic hot water pipes.

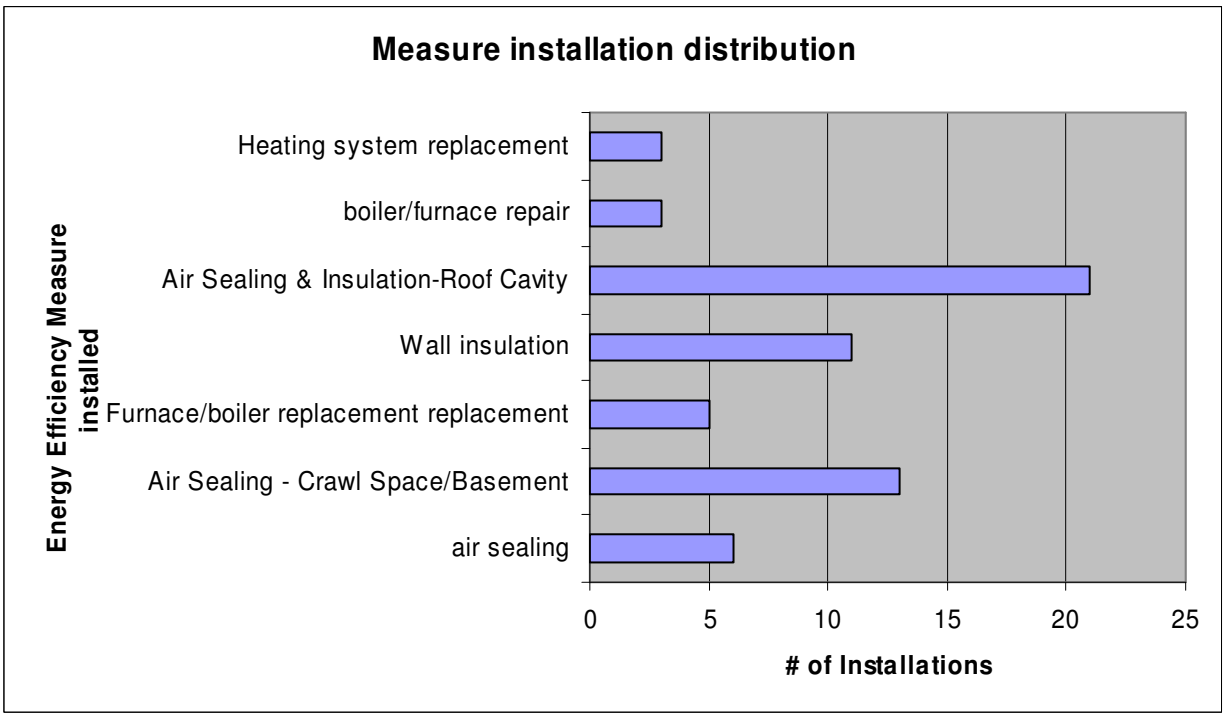

Figure 2: Distribution of actual installed energy efficiency measures

Project findings

After retrofits were completed, CNT Energy began monitoring the utility bills of the units' residents to determine what level of energy savings were achieved. For example, if the work was completed and systems were operating by October 31, 2009, CNT compared the gas usage from November 1 onward to the same time period in 2008-2009, normalizing the measured savings with respect to the severity of the winter. Because of the timing of this report, only preliminary data is available. Analysis is ongoing and will continue for two years post-retrofit installation.

The following graph shows preliminary reductions in natural gas usage from a four month period prior to the program, and following installation of energy conservation measures. Because of the scheduling of the retrofits, data is not available for all of the projects.

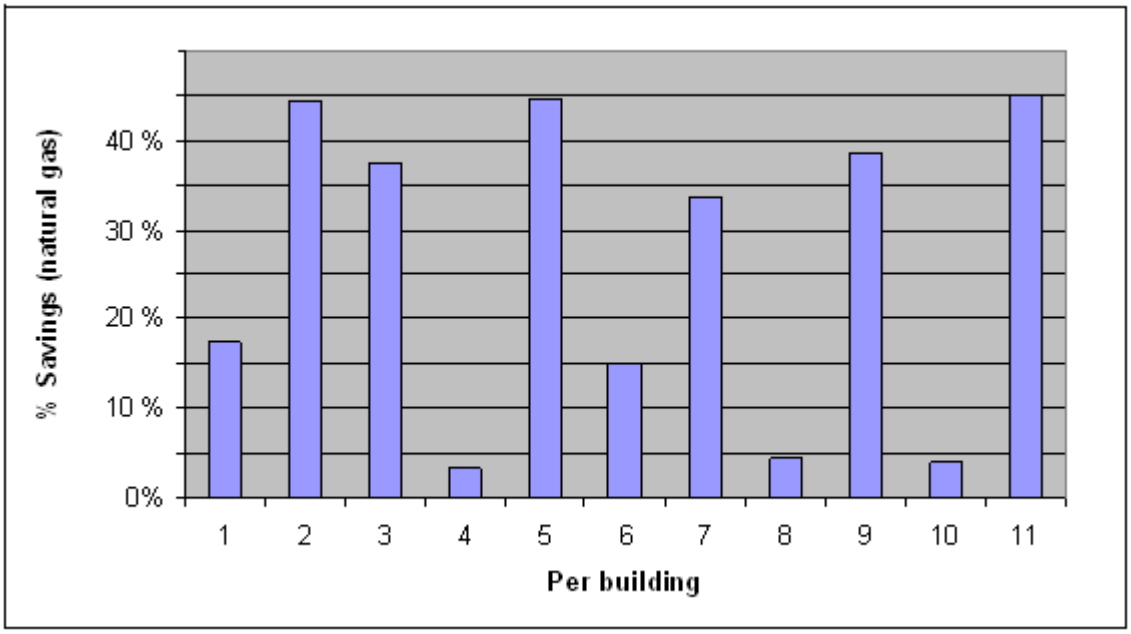

Figure 3: Reduction in Natural Gas Usage

A closer look at the natural gas usage intensity from buildings shows great variability, anywhere from 80 to 140 KBTU/SF (kilo BTUs per square foot of conditioned space). Another way of organizing this data is by building type because one goal of the Whole Home is to find cost-effective opportunities for efficiency over a diverse stock of housing. Figure 4 shows the Pre-Retrofit Natural Gas Usage Intensity (KBTU/SF of heated space) across building types. The high energy usage does correlate well with the conditions observed in the field including lack of insulation, inherently leaky construction and older heating systems.

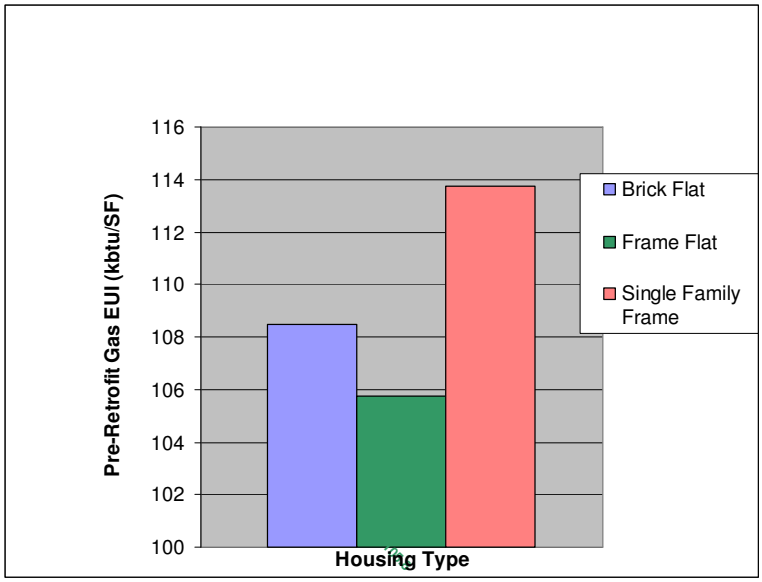

Figure 4. Per-Annum-Average Natural Gas Energy Use Intensity by Housing Type

In addition to the energy savings results, the Whole Home Energy Savers program provided unexpected insight into barriers that could prohibit scale-up of the home retrofit model. The first concerned the energy audit itself.

HERS Audits

The comprehensive HERS audit was troublesome in many ways. HERS ratings are best suited to rate the predicted energy usage of newly constructed homes. Auditors vary greatly in their ability to adapt this model to existing homes, and the energy modeling was time consuming. Because the REMRATE software that is used in HERS ratings was designed for new homes, it cannot model steam boilers and other variable field conditions that an older building stock like Chicago exhibits. Additionally, the REMRATE model was often not tuned to building specific energy usage. Another challenge was ensuring that the modeling results were calibrated to actual fuel data, and accounting for error and variability across different auditors in the hope of getting reliable and consistent results. A larger retrofit program would benefit from a simpler, less-time consuming and more accurate modeling tool that calibrated to the actual consumption data and more to the specific building type.

Not all work orders are created equal

In the program design, the auditor's report and associated work order was expected to provide details on installed item per item. However, there was great inconsistency in the data and format between auditors and even from report to report. There were also technical issues over which there is no consensus. Overall, the work orders required a lot of interpretation in order to maximize savings and be consistent about the type of work performed. The table below highlights the differences between the auditor recommendations and the final scope pursued by CNT and the Contractor

Table: 3 Case Study: 84 South Buffalo

Work Item	Auditor Recommendation	CNT final work item
1st Floor Space Heat	Remove old gas space heaters and tie into boiler that heats second floor	Install high efficiency modulating gas boiler to serve whole building and domestic hot water needs
2nd Floor Space Heat	Remains as same	Remove boiler and use new
Domestic hot water	Clean and tune existing upright domestic hot water heater	De-commision and use new boiler for domestic hot water

This example, though it was exceptionally complex, reflects the need for communication between auditors, program administrators and contractors. In the final scope, CNT conferred with the Contractor regarding proper sizing and chose to install a high efficiency modulating hot water boiler to service both units' heat and hot water needs. This turned out to be a better option and preliminary analysis of gas usages indicates a reduction of more than 40 % this year.

Health and Safety Concerns

Numerous health and safety concerns were addressed by the audit and retrofit process including radon testing, which was performed prior to any work. The testing process involved leaving a sample collector in the basement to be sent to the Illinois Certified Lab for analysis. Getting accurate and timely results was time consuming and complicated by customer error – often second radon kits had to be set up when the first test was not valid.

Mold and mildew were common even though most homes had leaky envelopes that precluded moisture build-up. Mold growth was encountered where bathroom fans vented to the attic instead of outdoors causing warm, moist air to hit the cold attic. Mold and mildew were also encountered in crawl spaces as a result of standing water.

Carbon monoxide (CO) and combustion safety analysis was a key part of the program. Old stove pilot lights were the primary source of CO. Also, some high levels of CO were found in appliance flue gasses. Prior to and following energy retrofit work the auditor performed a worst-case depressurization test to ensure that all appliances could draft safely in those conditions.

Thermal Boundary Issues

Although buildings with serious structural problems and thermal boundary issues were excluded from the pilot, the question of where to insulate and air seal was complicated by home layout and owner/occupant behavior. Enclosed and unconditioned rear porches were a common feature in 2-4 flat buildings. These were often used all year round, even though they were not intended as living units in the original building. Often, these areas were heated with a supplemental electric space heater. Some projects included expanding the thermal boundary of the home beyond the frame/brick structure and actually insulating and sealing the walls and ceiling of rear porches, to ensure that the work performed dovetailed with the way the occupants are using the home.

Discussion

The Chicagoland Home Energy Savers program was designed to test the viability and costs of obtaining 30% savings through weatherization, with combined gas and electric measures and a whole-home systems approach. Preliminary results from the program are promising, with an average overall energy savings of 26.2%. The 30% savings is not an unrealistic goal, especially for typical housing stock, with old heating systems, little or no insulation, and leaky building envelopes.

However, lower income home owners dominated the pilot building participants and the buildings had older heating equipment and no insulation in walls and attics. The implications of this selection criteria caution us about extrapolating the preliminary findings of 26% average natural gas savings to a broad and diverse housing market. If moderate/high income people are more likely to have newer or renovated homes with insulation and newer heating systems, the average savings will be harder to attain by traditional retrofit methods.

The project also identified a number of significant barriers to scaling up a similar energy efficiency program, both in convincing a larger audience to participation in whole-home weatherization, and serving these consumers well. These barriers are discussed below.

Costs and financing. For study purposes, the CHES program was completely subsidized. But for retrofits to occur on a large scale, funding will need to come from alternate sources. The budget of $10,000/unit is impractical at scale both from the utility company's perspective and the home owner buying the energy efficiency services. The issue of cost-effectiveness from a total resource cost perspective, what type and term of investment the average home owner considers acceptable and what finance mechanisms may work to make this a good deal for the average consumer must be factored in to any discussion of bringing whole home retrofits to scale. Likely, a combination of subsidy and finance tool to buy down the initial cost of the efficiency measures will be required. The essential challenge will be to leverage different funding sources and financial tools to adapt to a wide variety of end users ranging from low income to moderate/high income people, from old homes to newer more efficient homes, from owner occupied homes interested in long-term investments to property investors who want shorter payback periods.

The current economic climate also prohibits investment in energy retrofits. Consumers have little disposable income and are reluctant to make expensive purchases, even if they represent an investment with a reasonable payback, such as ECMs. Or, consumers may have mortgages that exceed the value of their home, and cannot take on additional debt. In addition, the long payback period suggested by a $10,000 investment will likely turn away many consumers who may want shorter returns on their investment. Lending institutions are under duress and small loans are not a priority, so financing may not be an option, even for a building owner is inclined to improve his building's energy efficiency.

Supply and demand. The concept of investing in energy efficiency has gained some momentum and visibility due to the current social context of concern about climate change, the emphasis on reducing energy use both locally and nationally, and funding for weatherization in the American Recovery and Reinvestment Act. But in Illinois, there is a widespread lack of understanding of the importance of energy efficiency on the part of consumers, at all levels of income. In Cook County, lower-income consumers have been reluctant to sign up even for free weatherization services offered by LIHEAP. Or if an informed consumer does invest in energy efficiency, that investment cannot be recouped as easily as the costs for a visible home improvement like upgrading a kitchen or bathroom.

The real estate market also does not recognize the value of building energy efficiency retrofits. (RW Ventures). Apart from undeveloped consumer demand and the economic climate, the energy efficiency

industry in Illinois requires significant market development. Weissbourd et al sees barriers of both supply and demand:

> "On the demand side, there is a need for more accurate, transparent and accessible information on what levels of retrofit activity will produce what savings for each homeowner, and on how that translates to increased asset value of the property. On the supply side, there is a need for a standardized and simplified process for the delivery of retrofits."

Methods and costs of effective weatherization. The CHES project's goals were to identify specific audit and retrofit approaches and technical standards, including which specific retrofits measures were appropriate for consideration during the program and what the role of outside energy auditors would be. The pilot identified technical issues over which there is currently no consensus or standards in the weatherization industry. Problems association with the lack of ventilation will become more acute as buildings are tightened to reduce air infiltration. Exhaust fans can help reduce moisture, but can further depressurize a home that is near the building tightness limit. More expensive and difficult to install energy recovery ventilation units are necessary to ventilate and balance whole home air pressure. The health and safety related problems observed in these buildings could be exacerbated by contractors without the experience to address them, and without the monitoring of program administrators or auditors, particularly auditors with BPI training, which focuses on safety.

Analyzing the effectiveness of HERS audits for achieving energy savings was one of the goals of the program. The audit reports were decidedly mixed in quality and in the information that was provided. In retrospect, a comprehensive HERS audit may not have been the best choice for this project, due to the inadequacies of the REMRATE model in analyzing existing buildings. It should also be noted that we did not actually receive "official" HERS ratings. The contracted auditors did not submit their analyses to RESNET for certification, due to the extra expense (reported as $100) and extra time this procedure would entail. Whether or not the quality of these audits would have been different if the audit had been certified is unknown.

On many of the projects, the final scope of work was developed after extensive consultations using information from the audit, the contractors, and CNT Energy, the program administrators. Sometimes having multiple actors resulted in duplication of work: for example, blower door readings were collected at three times: the initial HERS audit, following insulation/air sealing (by the contractor) and as part of the post-retrofit verification process (by a second energy auditor). These multiple visits not only increase costs, but are an inconvenience to homeowners. Comparing blower door results was complicated by differences in testing methodology, the inclusion of multi-unit buildings and variability across instruments. Thus these data could only be used with caution, and complicated the modeling results.

Whether the value of a customized energy audit, in terms of greater savings, compares favorably to a prescriptive program without auditing fees, remains unclear. The results from the HCBA program should provide important information regarding this question, this program compared weatherizations guided by audits to those performed by contractors. The best judgment about the usefulness of an energy auditor may be that "…the auditor is not needed when they are there but needed when they are not there." (Personal communication, J.Cavallo)

Next Steps. Because the final results of the program are not yet available, one of the most important questions – what was the cost for energy savings achieved – remains unanswered. The follow-up question of whether this cost is reasonable may have different answers, depending on who is answering. From the customer's perspective, the bottom line is simple: are the bill savings and additional comfort they experience in their homes worth the cost? This program, where retrofits were fully funded, does not answer that question. Any analysis must also be in the context of the current

economic climate. The complexity of operations in this program suggests that, left to their own resources, customers would not be inclined to pursue weatherizations, or be able to successfully navigate the existing marketplace if they did so.

For program administrators, the CHES pilot program identified several structural barriers to the efficient functioning of a weatherization marketplace, including funding restricted to type of fuel, the need for market development for contractors, and the need for additional "unrestricted" funds to address health and safety repairs. Even with the whole-home approach specified by this project, we found repeated examples of necessary repairs or installations that could not be classified as energy conservation measures, yet were essential

The funding for weatherization in the American Recovery and Reinvestment Act, the City of Chicago's goal of reducing home energy consumption, recent funding of efficiency programs from the gas and electric utilities, and the high energy usage of Chicago area buildings mean that there are many opportunities for growth in the weatherization industry. The lessons from the CHES program can help ensure that the best results - appropriate, cost-effective weatherizations that save energy - are achieved.

References

Baker, D. 2007. "*Energy Efficiency Portfolio Standard". Presentation at the ACEEE National Conference on Energy Efficiency as a Resource*. Oct.2007 http://www.aceee.org/conf/07ee/BAKERbs.pdf

Cavallo, J.; of Kouba-Cavallo Associates. 2010. Personal communication to authors, February 23

Center for Neighborhood Technology, 2008. Chicago Greenhouse Gas Emissions: An Inventory, Forecast, and Mitigation Analysis for Chicago and the Metropolitan Region. An Assessment Prepared for the City of Chicago. http://www.cnt.org/repository/CNT_Climate_Research_9.17.08.pdf

City of Chicago: The Chicago Climate Action Plan. 2008 http://www.chicagoclimateaction.org/

City of Chicago, Department of the Environment, in partnership with Katzenbach Partners, 2008. Horizon 1 strategic plan. Elements and approach for Horizons 2&3. November 18, 2008

Environmental Protection Agency, 2007. Market Barriers to Green Development Report Summary – Draft. July 2007

Goldberg, M., et al. 1998. *Energy Efficiency and Economic Development in Illinois*. Washington D.C.: American Council for an Energy-Efficient Economy.

Ludwig, P; Evens, A; Kotewa; L. *Cook County Energy Savers: How Energy Efficiency in Chicago's Multi-Family Buildings Has Evolved to Meet New Challenges From The 1980's to the Present Day*. ACEEE Summer Study 2008

Jennifer McGraw, Peter Haas, Linda Young, and Anne Evens, 2009. Greenhouse Gas Emissions in Chicago: Emissions Inventories and Reduction Strategies for Chicago and its Metropolitan Region. Journal of Great Lakes Research (2009), doi:10.1016/j.jglr.2009.11.010

RESNET National Standard for Home Energy Audits, 2010. http://www.natresnet.org/standards/audit/National_Energy_Audit_Standard.pdf

RW Ventures and O-H Community Partners, 2009. *Market Development for Building Energy Efficiency Retrofits*. White Paper

Thorne Amann, J., 2006. *Valuation of Non-Energy Benefits to Determine Cost-Effectiveness of Whole-House Retrofits Programs: A Literature Review*, ACEEE, May 2006, http://www.aceee.org/pubs/a061.htm

Thorne Amann, J.and A. Lowenberger, 2010. "Enhancing the Effectiveness of Home Energy Audits". *In proceeding of the AESP 2010 National Conference and Expo,* Tuscon, AZ