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

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ABSTRACT

The City of Chicago's Climate Action Plan identified reducing energy use in buildings as a primary goal, with the target of a 30% reduction in 400,000 residential housing units by 2020. But so far, established programs have only delivered 13-24% savings. The Chicagoland Home Energy Savers pilot 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. The findings will be used to guide the scaling-up of energy efficiency programs in Chicago.

The CHES pilot retrofit 80 housing units; both single family and small multifamily buildings were included. Savings will be measured by analysis of actual energy usage over a two-year period. The housing sample is representative of Chicago's diverse building stock, including 43% of units built before 1939, and a predominance of vintage masonry structures (52%), most with no insulation.

Another goal of the pilot is to analyze the effectiveness of HERS audits for achieving energy savings. Nearly one-third of Chicago's single family housing is brick Chicago Bungalows, 50 of these buildings are included in the pilot. Half of the bungalows have been evaluated with HERS audits, and retrofit with recommended energy conservation measures. The other half will receive prescriptive weatherization. Each groups' savings results will be compared.

This paper will report on the pilot, including lessons learned on how to address diverse housing stock and market barriers to performing retrofits at scale. Preliminary findings from energy usage analysis, with efficiency measures and associated costs and savings will be presented.

Introduction

This paper will discuss CNT Energy's progress and lessons-learned on the Chicagoland Whole Home Energy Savers (CHES) pilot program. In 2008, the City of Chicago released the Climate Action Plan (CCCAP). The Plan identified residential building energy retrofits as a substantial opportunity for emissions reductions. The plan called for retrofits at a scale of 400,000 units (approximately 40% of Chicago's housing stock over ten years, achieving 30% savings per home). The CHES pilot was designed to test the viability of this strategy, using a "whole home" approach and combined gas and electric home energy retrofits. A working group of energy efficiency practitioners (including energy auditors, utility company representatives, program implementers, and city and state energy efficiency liaisons) in the Chicago metropolitan area (locally referred to as Chicago-land) helped design the pilot. The test subjects included a representative sample of Chicago housing types, including single and small multifamily

buildings, of both frame and masonry constructions. An additional sample of brick bungalow buildings received retrofits through a process managed by the Historical Chicago Bungalow Association.

Energy Efficiency Grows in Illinois

The State of Illinois had a historically low record of investment in energy efficiency, both by the government and large investor–owned utility companies and Chicago reflects this disinvestment. In 2003, Illinois ranked 35th in energy efficiency spending per capita (and as recently as 2007, Illinois ranked last in measured percentage of public benefit funding supplied by utility revenues among twenty-eight states (York and Kushler, Baker). This status changed dramatically when gas and electric utilities unveiled new efficiency portfolios and Illinois jumped to seventh; representing an increase in the percentage of public benefit funds as utility revenues from nearly zero to roughly 2%. Illinois is experiencing growing pains as a marketplace and service industry that has operated on the margins of the economy is being asked to quickly replicate its production many times over.

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 in Chicago. Nearly 70% of these units are single family homes and two to four unit buildings and approximately half of these were built before 1940 (CCAP 2008). The majority of the buildings in the CHES sample group were older residences due to the predominance of older housing in Chicago's existing building stock; and the likelihood that weatherizing these "energy-needy" buildings would achieve the greatest savings.

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 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 (CCAP).

The Chicagoland Home Energy Savers project was proposed to test the viability of achieving 30% energy savings from weatherizing a representative sample of existing housing. The project was funded by Peoples Energy[1], a natural gas utility, and the State of Illinois. The Peoples Energy funding is generated by a line item on customer's bills for energy efficiency programs. Another goal of the project was to convene a Whole Home Working Group (WHWG) to discuss some of the challenges inherent in scaling up weatherization. The group helped to design the pilot program. To evaluate the results, the energy usage in these housing units will be monitored for two years.

[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.

The Whole Home Working Group

The Whole Home Working Group (WHWG) consists of energy auditors, utility company representatives, program implementers, and city and state energy efficiency officials, among others. The working group was convened to focus on key topics that shaped the pilot program; over a series of ten bi-weekly meetings. The group discussed specific audit/retrofit approaches and technical standards, the role of outside energy auditors and which retrofit measures were appropriate for consideration as part of the pilot. Other topics included an examination of 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 housing units to be qualified, or able to benefit from weatherization, and the specific energy efficiency measures that would and would not be options in the pilot program.

Project Design

The WHWG identified several typical types of housing that were representative of Chicago-area housing stock for inclusion in the project. In general, there was a distinction between brick versus frame construction and single family versus two to four unit buildings. A more modern housing type, ranch style homes with no basements, was 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 +/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	No basement, Single family frame or brick walled home, often with attached garage, typical of suburban neighborhoods

Nearly one-third of Chicago's residential buildings are bungalows, built between 1910 and 1940. The bungalow is so ubiquitous that it has been recognized as a specific architectural and social entity. A delegate agency, the Historic Chicago Bungalow Association, was established to provide programs and services to the bungalow belt residents. Bungalows include over 80.000 households of all income types. Through the CHES program, the HCBA was funded to administer whole home retrofits for 50 homes.

Selection of Participants and Building Types

The pilot design provided full funding for most of the weatherizations, therefore most of the buildings included in the study received the services and installation of up to $10,000 worth of energy efficiency improvements (per dwelling unit) at no cost. This subsidization was established to accommodate the pilot's short timeline. Bungalow homeowners with higher incomes were asked to pay for a portion of the weatherization costs. CNT Energy worked with nonprofit housing groups to locate low to moderate income households that could most benefit from this allocation. In order to further identify buildings that would provide the best test subjects, these factors were used to evaluate the applicants:

- Stable occupancy in the building, in order to be able to compare historic energy usage
- Intact thermal barriers – i.e., the occupied area has not been extended beyond original structure's layout, or the basement or attic has not been remodeled as a second living unit
- The building's residents were 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 paid for their utilities. Tenants where the landlord pays for heat are less likely to be motivated to reduce natural gas usage
- Older mechanical systems were in use in the building

Other factors were grounds for exclusion from the program, including:

- The building structure, overall, was in a state of disrepair
- The roof was leaking or otherwise not stable
- The building had or was likely to have significant water damage or flooding
- Radon levels of >4pCi/l were found
- Conditions that were a threat to health and safety such as the presence of lead paint and asbestos. The presence of old electrical connections (knob and wire) also precluded the addition of insulation
- Utility service had been shut off
- The building was not ready for construction due to excessive clutter
- The building was financially at risk of foreclosure
- The building did 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 an unexpected barrier in the current constrained economic environment.

Pre-Audit Conditions

CNT Energy audited 45 housing units to choose those homes that would be weatherized. Based on the criteria developed by the WHWG, the following distribution of thirty housing units in 17 buildings were retrofitted (Table 2)

Table 2: Distribution of Housing Types and Units in CHES Program

	# of units	
Building Type	**Single Family**	**Multi-family**
Frame (wood)	8	9
Brick or Masonry	50*	9
Frame & Masonry	4	

* Chicago Bungalows

Natural gas is the most common fuel for space heating in older Chicago homes, and was the primary fuel in all program buildings. Ten of the 17 buildings were equipped with furnaces, and four had boilers. Three homes had older gas vented space heaters in lieu of, or in addition to, central heating plants. Historically, these space heaters were commonly in use, but current building codes restrict their installation. In addition to operating at low efficiency, space heaters represent a safety liability; some insurance companies are unwilling to write policies for buildings with these units. Therefore, the removal of space heaters and installation of gas furnaces and associated duct work was considered a necessary and ultimately cost-effective retrofit, although the capital investment was higher than a simple furnace upgrade. This retrofit became even more crucial as building envelopes were tightened, reducing air exchange between the indoors and outdoors. Most homes did not have central air conditioning, window air conditioners are typically found in the Chicago's older building stock.

The majority of buildings in this project had little or no insulation. Several homes had some ceiling insulation, but less than the recommended R-38 level. Where insulation was present it was often poorly installed and in degraded conditions. Blower door results from the pre-retrofit audits were often higher than 5,000 CFM50 (cubic feet per minute at 50 pascals) indicating great potential for reducing air infiltration. 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 The WHWG identified three certification programs that qualified auditors to produce comprehensive home energy audits: RESNET (Residential Energy Services Network) certification of Home Energy Raters, Building Performance Institute (BPI), and IHWAP (IL Home Weatherization Assistance Providers) certification. For this project, we used auditors that were certified by both RESNET and BPI.

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 independent energy auditors were contracted for a HERS (Home Energy Rating System) Audit as the standard audit for this program. 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 3: 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

If the post retrofit verification identified any problems with the installation, these were resolved by CNT Energy staff. Then CNT began monitoring the energy savings resulting from the work.

Project Installations

The specific energy conservation measures (ECMs) that were installed in each housing unit were based on the recommendations from the energy audits performed by third party auditors, summarized in a work order. The installation packages were budgeted at an average of $10,000 per unit. Figure 1 below indicates that natural gas makes up the large majority of the energy consumed at the subject properties; all used natural gas for space and for domestic hot water heating. 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.

Figure 1. Pre-Retrofit Energy Use Intensity

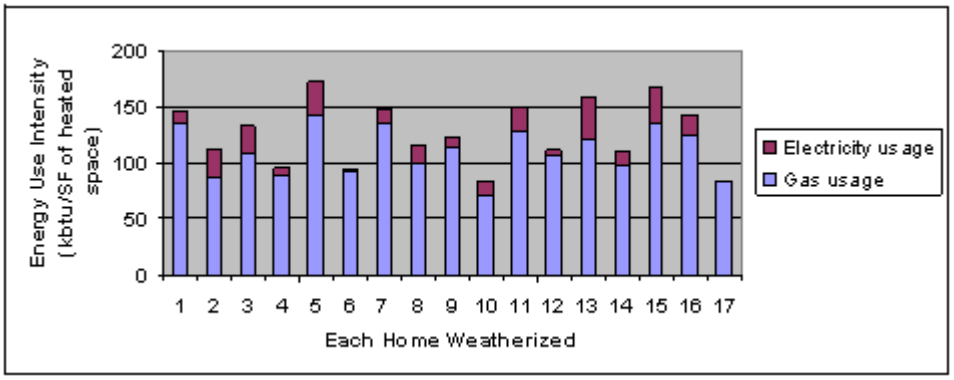
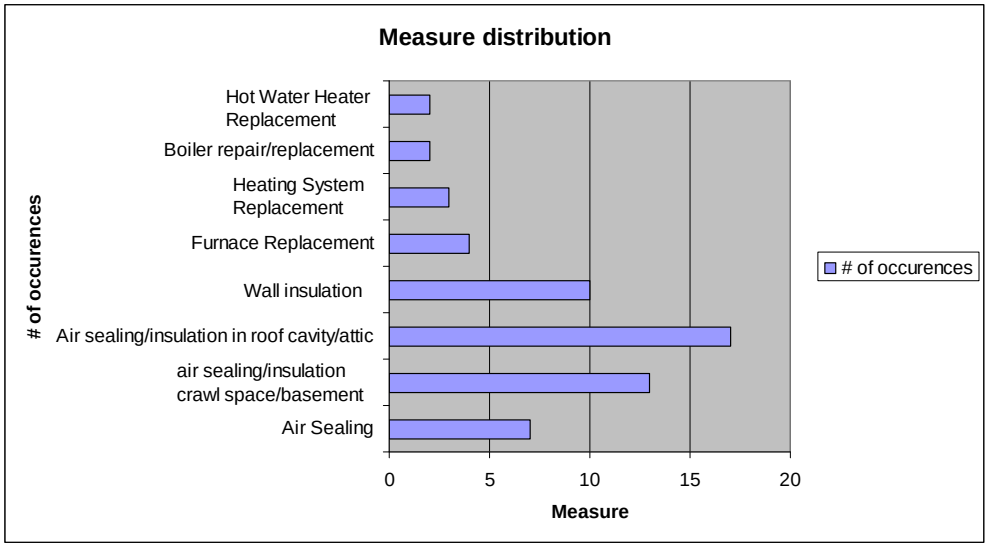


Figure 2 below shows the frequency with which the main efficiency measures were installed. Insulation and air sealing were the most common, occurring in every scope of work. Heating system upgrades including furnace replacement and removal of gas space heaters were also frequent. Low cost measures that were installed in every home included high efficiency compact fluorescent light bulbs, low flow shower heads, and insulation around exposed domestic hot water pipes. Despite the fact that smoke alarms and carbon monoxide detectors have been required in Chicago for many years, these devices were often missing, and were installed as necessary.

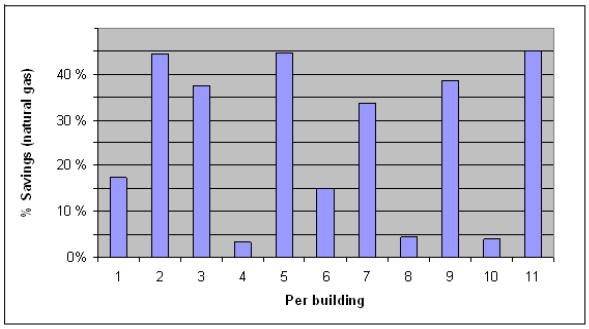
Figure 2: Distribution of Actual Installed Energy Efficiency Measures



Project Findings

The following graph shows preliminary reductions in natural gas usage from a four month period of winter months 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. The cost of energy is not specifically noted due to the difficulty in predicting natural gas prices over a short (1-2 year) period,

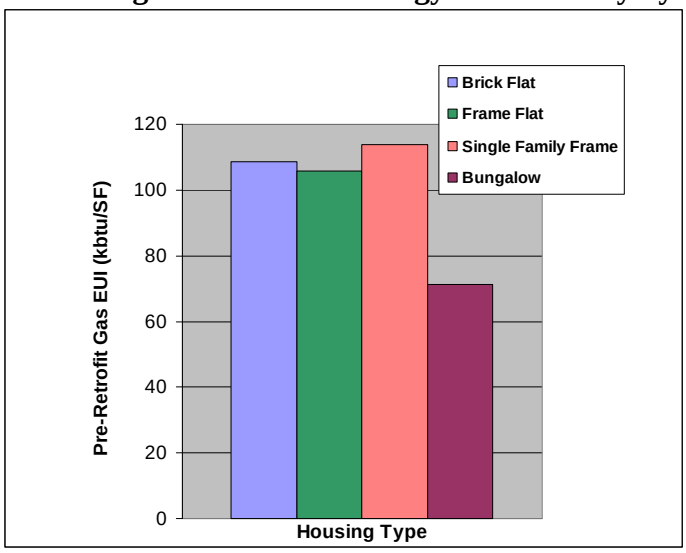
Figure 3: Percentage Reduction in Natural Gas Usage (Weather Adjusted)



The natural gas usage intensity from building to building shows great variability, ranging from 80 to 140 KBUTs/square feet of heated space. Buildings with lower savings were largely brick buildings (with no wall cavities to insulate) and buildings where gas data was incomplete or incorrect; additional data on usage should improve this analysis.

To address the Whole Home goal of identifying cost-effective opportunities for efficiency over a diverse stock of housing, we also calculated these data by building type. Figure 4 shows the pre-retrofit natural gas usage intensity (KBTU/SF of heated space) across building types. The natural gas usage intensities of single family frame homes are noticeably higher than those of multifamily units. The high energy usage correlates well with the conditions observed in the field including lack of insulation, inherently leaky construction and older heating systems.

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



The ongoing monitoring of the energy usage in these housing units is necessary to determine if the 30% reduction goal has been met. However, in addition to the energy savings results, the CHES program provided insights into several structural 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 identified by the WHWG as the "gold standard" of auditing due to the standardization of software and training. We anticipated that the audit reports would provide consistent detail in diagnostic testing, analyses and recommendations for retrofits. In reality, the completed audits varied greatly. We subsequently learned that HERS ratings are best suited to rate the predicted energy usage of newly constructed homes, not existing buildings. Auditors vary greatly in their ability to adapt this model to existing homes, and the energy modeling itself was time consuming. Because the REMRATE software is designed for new homes, it cannot model steam boilers and other variable field conditions that an older building stock like Chicago's 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 usage data. Accounting for error and variability across different reports was necessary in the hope of obtaining reliable and consistent results. CNT carefully reviewed modeling results and projected savings and applied a consistent algorithm to further refine the projected savings. These projections will be compared to the actual energy usage.

In the program design, the auditors' reports and associated work orders were expected to provide a detailed scope of work, with installed item per item costs. However, there was great inconsistency in the data and format between auditors and even from report to report. Overall, the work orders required considerable interpretation in order to maximize savings and be consistent about the type of work performed.

A two story single family building, for example, used space heaters on the first and second floors, in addition to an older boiler and older upright hot water heater. The auditor recommended removing the space heaters on the first floor and tying into the boiler that heated the second floor, while retaining the second floor space heaters and simply cleaning and tuning

the existing hot water heat. CNT Energy conferred with a Contractor about a boiler to service both unit's heat and hot water needs. A properly sized, high efficiency modulating hot water turned out to be a cost effective and higher-quality option, with initial results indicating natural gas usage reduction of more than 50%.

The bungalow weatherizations will also provide data on the impact of audits in achieving energy savings. Half of the bungalows were evaluated with HERS audits, and retrofit with recommended energy conservation measures. The other half received prescriptive weatherization consisting of air sealing and insulation guided by blower-door, HVAC tune-up and some electric measures (compact fluorescent light bulbs, appliance replacement).

The Unhealthy Home

The CHES program revealed numerous and unexpected health and safety issues that, in some cases, had no easy or cost-effective solution.

Funding from the State of Illinois enabled us to have radon testing performed for the buildings in the study. The testing process involved leaving a sample collector in the basement to be sent to a certified lab for analysis. Getting accurate and timely results proved to be exceptionally time consuming and complicated, mostly due to customer error. Residents invariably sent the kit in after too much time had elapsed, or packaged the kits incorrectly, resulting in invalid results. Often second and even third radon kits had to be delivered and set up. Buildings where radon was present were excluded from the study. But because no funding for radon remediation is available in Illinois, these lower-income property owners were left with a new problem that required fixing, but no resources to do so.

Carbon monoxide (CO) testing and combustion safety analysis were a key part of the program, as the tightening of these homes by air sealing increased the likelihood of CO levels would be dangerous. 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. High CO levels were common – sometimes in appliance flue gases, but old stove pilot lights were the primary source of CO. and stoves replacement was not an approved expenditure. In these cases, CNT Energy staff was able to improve the combustion of the existing stoves by cleaning and maintenance. These same conditions are undoubtedly present in other buildings, and the lack of CO detectors exacerbates the problem.

Mechanical ventilation, even in kitchens and bathrooms, is uncommon in older buildings in Chicago. Most homes had leaky envelopes that precluded moisture build-up, although mold and mildew were observed during this program. 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 present in crawl spaces as a result of standing water.

The Shifting Thermal Boundary

In the CHES program design, buildings with serious structural problems and without an intact thermal boundary were to be excluded from the pilot. However, alterations to existing layouts were so common that this criterion could not be enforced. Enclosed and unconditioned rear porches were a common feature in many buildings, and these rooms were often used all year round, even though they were technically not part of the building structure and often of poor construction quality. The supplemental electric space heaters that were often present in these

areas contributed to high energy use. 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. While this retrofit was not optimal from an energy efficiency standard, it was necessary 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 to 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 savings data from the bungalow projects will provide insight into these results.

The process 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.

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 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 and O-H Community Partners 2009)

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. 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.

Some funding for energy efficiency from investor-owned utilities is becoming available in Illinois, but these programs do not allow for the co-delivery of gas and electric measures, which is optimal for assuring the most effective measures are installed. 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 (e.g., health and safety repairs)

Apart from undeveloped consumer demand and the economic climate, the energy efficiency industry in Illinois requires significant market development. In a white paper produced as part of a survey of the energy efficiency services, Weissbourd 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 (RW Ventures and O-H Community Partners, 2009)."

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 audits, all of 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.

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.

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 The HCBA program was designed to test whether the energy saving results obtained by a quality contractor will match those that are customized per an energy audit, but these results are not yet available, and may only be applicable to this specific building type. 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)

Because the final results of the program are not yet available, one of the most important questions – what was the cost for energy savings – 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. 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.

The funding for LIHEAP weatherization and other programs 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.

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