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Evaluation of Missed Energy Saving Opportunity Based on Illinois Home Performance Program Field Data: Homeowner Selected Upgrades Versus Cost-Optimized Solutions

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Partnership for Advanced Residential Retrofit

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Prepared for:

Building America

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Definitions

BEopt™	Building Energy Optimization software
CCS	Chicagoland Characterization Study
DOE	U.S. Department of Energy
EUI	Energy use intensity
IHP	Illinois Home Performance with ENERGY STAR
PARR	Partnership for Advanced Residential Retrofits

Executive Summary

This report builds and expands off of previous research by collecting and evaluating data from 800 Illinois Home Performance (IHP) retrofits. This study investigates homeowner measure package choices in the Illinois Home Performance with ENERGY STAR® (IHP) program compared to cost-optimal choices determined through Building Energy Optimization (BEopt™) modeling software. This research was based on evaluating actual retrofit measure selection in 800 homes, grouping the homes into one of the 12 Chicagoland single-family housing archetypes, determining the most cost-optimal measure mix for each housing archetype using BEopt. The cost-optimal measures were then compared with actual measure installations for each housing archetype using BEopt. The main objectives of this study are to:

- Model overall gas and electricity savings from the common measures installed in IHP for 12 of the 15 housing archetypes in Chicago's building stock.

- Compare savings and optimal measure packages between actual measures installed and recommended measure packages as modeled through BEopt. The study also made general observations about houses that received retrofits through IHP compared to the average housing stock in Chicago.

IHP homes are actual homes that have qualified and been through the IHP utility program. As of the time of this study, the majority of homes receiving IHP recognition were from the Chicago metropolitan area. Individual homes that received IHP recognition were matched with corresponding housing group archetypes from the *Chicagoland Single-Family Housing Characterization* study (CCS). The IHP homes used in this study were able to be matched to 12 out of the original 15 housing groups.

After grouping the IHP homes, this study identified the type and frequency of common measures installed by homeowners through IHP. Using BEopt software, cost-optimal measures were identified and IHP common measures were evaluated for each housing group. Comparison between the actual measures installed in IHP homes and BEopt recommended cost-optimal measures indicates that there is a large difference in measure selection; however, default cost assumptions were used in BEopt modeling, and differences were discovered between these costs and the actual measure cost in northern Illinois. IHP homes follow roughly the same distribution across housing groups as the CCS study distribution. Homes that participated in the IHP program are older than what would be expected and represent roughly the same distribution of brick and frame construction as what was found in the CCS. Findings from the study included:

1. For most housing archetypes in IHP, the homes received more measures than BEopt-recommended cost-optimal measure packages. The exception was in brick homes where fewer measures were installed than BEopt-recommended cost-optimal measure packages.

2. IHP measure packages result in greater EUI reduction in frame homes and older homes than in newer homes and brick homes.

3. Measure packages installed during an IHP retrofit result in significantly more gas savings than electricity savings (because the IHP houses are in a heating climate and use gas to heat homes), a finding consistent with BEopt modeling.

The methodology and findings of this study are important because they provide valuable feedback for the current IHP program and guidance into how other whole-home retrofit programs can utilize large datasets in self-evaluation to improve the overall cost effectiveness of installed measure packages. One of the most important conclusions of this study is that linking home categorization to standardized retrofit measure packages provides an opportunity to streamline the process for single-family home energy retrofits and maximize both energy savings and cost effectiveness. This report outlines a methodology that may be useful for similar programs to use when evaluating measure selection and cost effectiveness.

1 Introduction

1.1 Background

The five-county Chicagoland region contains more than 3.3 million homes, many of which are aging, energy intensive, and costly for homeowners to maintain (Spanier et al. 2012). Substantial potential exists to reduce energy use and increase the comfort, safety, and durability of these homes. Despite the retrofit industry's rapid growth in northern Illinois, the scale needed to realize this potential is still lacking. Many programs exist in the Chicagoland region to help homeowners make energy-saving improvements to their homes. Because these programs have different goals, employ different program structures, incorporate homeowner decisions, and address a variety of housing types, individual retrofits may differ substantially in the types of improvements made and the level of savings achieved. With this in mind, the Partnership for Advanced Residential Retrofits (PARR) will evaluate the measure packages installed in homes achieving Illinois Home Performance with ENERGY STAR® (IHP) certification on the basis of cost optimality and magnitude of energy savings.

Building Energy Optimization (BEopt™) software, developed by the U.S. Department of Energy (DOE) National Renewable Energy Laboratory, can be used to identify cost-optimal residential retrofit measure packages while taking into account a home's size, construction, occupancy, vintage, location, and utility rates (Christensen et al. 2006). BEopt creates models using a systems integrated approach and produces recommendations that can involve improvements to a home's thermal envelope, equipment, construction materials, and construction practices (Christensen et al. 2006). BEopt has been used extensively in previous PARR research to define cost-optimal retrofit measure packages for different housing types in the Chicagoland region (Baker et al. 2013; Spanier et al. 2012). This study uses prior PARR research that determined savings from cost-optimal measure packages determined by BEopt for different housing archetypes and compares to savings from actual measures installed in homes achieving IHP certification. Many residential retrofit programs are moving toward the Home Performance with ENERGY STAR framework, which will be further discussed in this report; thus, it is important to scrutinize program outcomes for missed potential and identify potential areas for improvement.

1.2 Illinois Home Performance with ENERGY STAR

Illinois Home Performance with ENERGY STAR, also known as Illinois Home Performance (IHP), is Illinois' version of the national Home Performance with ENERGY STAR program. IHP serves as a statewide platform that links new and existing Illinois whole-home retrofit programs and awards a common Certificate of Completion to homeowners who complete the IHP process. These residential retrofit programs, called Program Providers, offer quality assurance support and financial incentives for various energy-saving measures and capture household-level data on retrofits. IHP Program Providers include Ameren Illinois ActOnEnergy and Warm Neighbors Cool Friends, Energy Impact Illinois, Delta Weatherization Energy Efficiency Program, Historic Chicago Bungalow Association Energy Savers Program, and the Nicor Gas-ComEd Home Energy Savings Program.

IHP takes a systems-based approach to home energy upgrades that requires participating contractors to first perform a diagnostic energy assessment, then make targeted improvements identified during the assessment, and then verify the improvements by retesting performance. All work is completed to Building Performance Institute Building Analyst and Envelope Professional standards.

Upon completion of an IHP job, the State of Illinois awards homeowners a Certificate of Completion at either a Silver or a Gold level. These certificates are recognized by Midwest Real Estate Data LLC, the Northern Illinois multiple listing service, and can be uploaded to other Illinois multiple listing service systems. The intent of the Certificate of Completion is to capture the value of the improvements that have been made—which are often invisible—allowing homeowners to recoup some of that value during home sales and attracting homebuyers who are interested in purchasing efficient homes.

IHP offers homeowners and contractors a variety of additional resources, including a building science hotline, an online listing of participating contractors, building science trainings, Building Performance Institute certification rebates, and an equipment loan program.
Visit www.illinoishomeperformance.org for more information. IHP is sponsored by the Illinois Department of Commerce and Economic Opportunity.

1.3 Preceding Research by PARR

PARR's *Chicagoland Single-Family Housing Characterization* study (CCS) used property assessor data and utility billing history to identify 15 distinct housing groups in the Chicagoland region (Spanier et al. 2012). Through the use of BEopt modeling analysis, the study defines energy upgrade packages for each group that result in an optimal level of energy savings. Based on potential annual site energy savings and the frequency of a particular housing group within the housing population, the study identified housing groups with the largest savings potential, and made programmatic recommendations.

PARR's successive report, *Analysis of Illinois Home Performance with ENERGY STAR Measure Packages* (Baker et al. 2013), compared BEopt-modeled energy savings from 19 homes that had recently participated in the then-nascent IHP program to savings from cost-optimal measure packages as reported in the CCC report. These homes represented 8 of the 15 previously identified housing groups and nearly 35% of the Chicagoland residential building stock. The study found that the measures installed during IHP upgrades did not match BEopt-defined optimal measure packages. The installed cost of IHP measure packages cost homeowners, in some instances, more than twice as much as BEopt-recommended measure packages. The authors also identified various behavioral biases, informational deficiencies, and financial incentives that may influence homeowners and contractors to install suboptimal measure packages in IHP homes.

1.4 Relevance to Building America's Goals

This project contributes to Building America's goal of "ensur[ing] the reliability, effectiveness, and persistence of energy upgrades when applied to new and existing homes" by analyzing missed energy saving opportunities in the fast-growing Illinois residential retrofit market and identifying potentially optimal retrofit investment decisions. Additionally, this research can help guide program development and ensure that homeowner and program funding is allocated in the most effective ways. These research outcomes address the Building America goal of providing "technical support for new and existing home market transformation programs." This project, which is based on both field data and model-generated recommendations, may be particularly useful for calibrating rebates and other measure incentives, for targeting marketing toward retrofit candidates with high savings potential, and for educating contractors and homeowners about the differences between cost-optimal and commonly installed measure packages.

This research is specifically relevant to aging housing populations in cold climates; the housing stock of Chicagoland comprises nearly all U.S. cold-climate architectural styles and was largely constructed without consideration of energy efficiency. The CCS study reports that the three most prevalent residential housing types represent a potential savings of more than 100 million therms of source energy if all homes of those types were retrofitted according to PARR's BEopt-recommended measure packages (Spanier et al. 2012). This region is also the recipient of substantial investment toward energy efficiency improvements in recent times (Culltar et al. 2012), and is therefore a productive area for research aiming to close the gap between existing home performance practices and cost-optimal practices.

1.5 Study Rationale

Illinois Home Performance Case Studies Follow-on builds off of previous work by collecting and evaluating data from approximately 800 IHP retrofits (Baker et al., 2013). This study investigates homeowner measure package choices and the missed opportunity for cost-effective energy savings within a consistent program framework. IHP's objective is to infuse a level of consistency across the residential retrofit programs arena, thereby reducing market confusion and promoting retrofits. However, as IHP is a market-based program, homeowners have the final decision on which measure package will be installed in their homes, meaning that cost optimality may not drive homeowner decisions. The goal of this research is to evaluate the potential missed opportunity among the housing characterization archetypes and to determine if IHP field installed measures packages may be closer to optimal, based on modeling, for certain housing types, and further apart for others.

2 Research Methodology

This research builds on previous Chicagoland housing characterization work by including the first 800 homes that have been through the IHP retrofit program. Data analyzed in this study are drawn from actual retrofit measure selection, Chicagoland single-family housing group archetype demographics,[1] and BEopt modeling software cost optimization (Spanier et al. 2012). BEopt version 1.1 was used for all analysis. The methodology described in this section will answer the outlined research questions and serve to shed light on how real-world residential whole-home retrofit programs compare with cost-optimized whole-home retrofit modeling.

2.1 Research Questions

- How do modeled optimal energy savings for each housing type compare to the energy savings derived from typically installed measure packages for that housing type?
- How many homes have participated in IHP for each of the 15 housing types?
- What are the characteristics of retrofits currently occurring under the IHP program platform in northern Illinois?
- What measure packages are commonly installed for each of the 15 housing types?
- What is the missed energy savings opportunity resulting from not installing cost-optimal measures?
- How do large datasets help explain homeowner decision-making behavior and energy savings objectives?
- What housing types should existing programs focus on to provide maximum cost-effective energy savings?

2.2 Data Collection and Analysis

2.2.1.1 Data Collection

The first 800 homes to achieve IHP recognition provided the data utilized in this study. Retrofit work was completed on these homes between January 2011 and January 2013. The 800 homes are all located in Illinois; the majority of the homes are located in the Chicago metropolitan area. For the purposes of this study, the Chicago metropolitan area consists of Cook County only. Data from the 800 IHP homes were geocoded and each home was assigned to one of the 15 housing groups identified by the Chicagoland Characterization Study, which characterized 432,605 homes in Cook County, representing approximately 30% of the total single-family housing stock in the Chicagoland area (Spanier et al. 2012). Geocoding was conducted using ArcGIS's US Streets Geocode Service. Of the 800 homes, 504 (63%) were located in Cook County and also characterized as one of the 15 housing groups. Roughly 2% of the total homes were unable to be geocoded and were thus excluded from the study. Housing groups 1, 2, and 9 were excluded from this study because none contained more than one IHP home. The three excluded housing groups represent 8.5% of the Cook County housing stock (Table 2).

After the IHP homes were assigned to housing groups, the individual measures completed during each retrofit were ranked in order of frequency. Common measures were defined as those that occurred in at least 15% of IHP homes for each housing group. A frequency of 15% was chosen

[1] Housing characterization is based on the CCS study.

because it excludes rare measures and potentially random occurrences of measures, especially in housing groups with small sample size; however, because the frequency of measures after the two most common measures (air sealing and attic insulation) drops substantially, a low cutoff point—such as 15%—captures measures that are occurring with enough frequency to be considered non-random or common. These measures are listed in Appendix A.

2.2.1.2 BEopt Modeling Methodology

In order to determine the difference between energy savings associated with IHP common measures and BEopt-recommended measures, baseline energy consumption was modeled using BEopt for an average home in each housing group. All baseline models utilized the existing conditions reported by the CCS (Spanier et al. 2012); for example, a pre-retrofit IHP group 4 home was identical to a pre-retrofit CCS group 4 home. Once baseline models were created for all 13 housing groups, two distinct retrofit scenarios were modeled for each housing group: Upgrading the baseline using IHP common measures, and upgrading the baseline using BEopt-recommended cost-optimal measures.

The purpose of modeling these two scenarios was to determine the impact that each scenario's collection of measures would have on a housing group's energy use intensity (EUI). EUI is a unit of measurement for total energy used per square foot per year and takes into account both electricity and gas consumption. In order to accurately compare measures in the two modeled scenarios, several measures had to be modified or excluded from the study. Measures were excluded from the modeling because of BEopt software limitations or significant housing construction differences between the two scenarios.

The following list displays changes or exclusions to the modeling assumptions developed by the CCS and used in this study:

- Crawlspaces were assumed to be 50% uninsulated and serve the same structural role as basements (housing groups 7, 11, 13, 14, and 15).
- Rim joist insulation was not modeled (housing groups 4, 6, 7, 13, 14, 15).
- Weather stripping was not directly modeled; rather, overall air leakage reduction was modeled by BEopt (housing groups 7, 14).
- Furnace cleaning and tuning were not modeled (housing groups 7, 13, 14).
- Floor insulation was not modeled (housing groups 6, 8, 12).

3 Results

The results presented below include analysis of both housing group demographics and the impact of different measure packages on EUI. In addition to measure package-level impacts, this study also analyzed how individual measures impact overall reduction in EUI.

3.1 Illinois Home Performance Demographic Comparisons

Figure 1 shows examples of three archetype homes in Chicago. Figure 2 compares the distribution of IHP homes and homes categorized in the CCS across the 15 housing groups. Overall, IHP homes followed roughly the same distribution across housing groups as the distribution reported by the CCS. Drastic exceptions include housing group 7, which is over-represented by IHP, and housing group 12, which is under-represented by IHP (Figures 2 and 3). The top three housing groups targeted by the CCS were 14, 12, and 7; 267 of those homes are included in this analysis (Figures 1 and 2).

Figure 1. Photos: CCS housing groups 14, 12, and 7 (right to left)

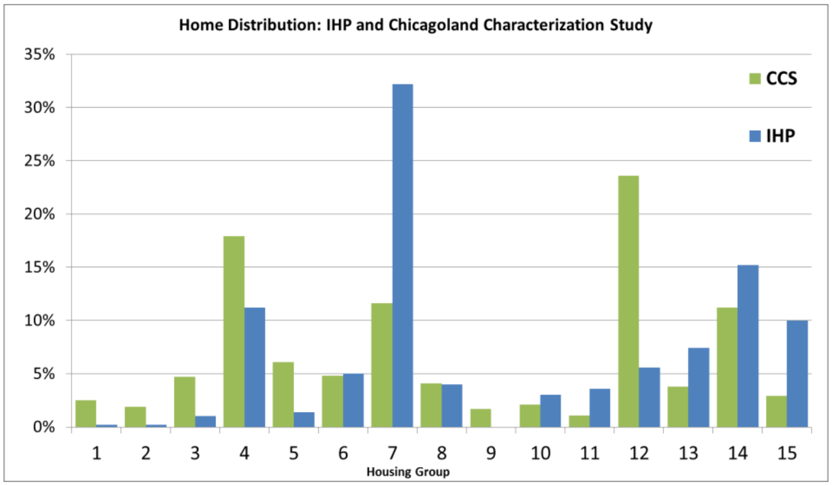

Figure 2. Distribution of IHP- and CCS-characterized homes across the 15 CCS housing groups

Table 1. IHP Versus CCS Housing Group Demographics

Group	Frame	Year Built	# Stories	IHP #	% of IHP	CCS #	% of CCS
1	Brick	Post-1978	1–1.5	1	0.2	10,856	2.5
2	Brick	Post-1978	Split level	1	0.2	8,417	1.9
3	Brick	Post-1978	2	5	1	20,530	4.7
4	Brick	1942–1978	1–1.5	57	11.2	77,435	17.9
5	Brick	Pre-1978	Split level	7	1.4	26,445	6.1
6	Brick	1942–1978	2	25	5	20,755	4.8
7	Brick	Pre-1942	1–1.5	162	32.2	50,239	11.6
8	Brick	Pre-1942	2	20	4	17,629	4.1
9	Frame	Post-1978	1–1.5	0	0	7,318	1.7
10	Frame	All years	Split level	15	3	9,225	2.1
11	Frame	Post-1978	2	18	3.6	4,544	1.1
12	Frame	1942–1978	1–1.5	29	5.6	101,957	23.6
13	Frame	1942–1978	2	37	7.4	16,411	3.8
14	Frame	Pre-1942	1–1.5	76	15.2	48,365	11.2
15	Frame	Pre-1942	2	50	10	12,479	2.9
Total				503	100	432,605	100

There is significant potential for IHP to target housing groups 4 and 12. Homes in housing group 4 were built between 1942 and 1978, have brick construction, are 1 to 1.5 stories, have an average square footage of 1,217, and have an average EUI of 129.6. Housing group 4 represents 11.2% of the IHP housing population, but 17.9% of the Chicagoland housing stock. Homes in housing group 12 were built between 1942 and 1978, have frame construction, are 1 to 1.5 stories, have an average square footage of 1,185, and have an average EUI of 135.3. Housing group 12 represents 5.6% of the IHP housing population, but 23.6% of the Chicagoland housing stock (Table 1). Overall, IHP homes had less participation in housing groups that the preliminary study identified as having lesser cost-effective energy savings potential, as well as less participation in housing groups that are rare in Cook County, such as groups 1, 2, and 9. These observations are important to the IHP program because certain housing groups represent greater opportunities for energy savings than others.

While distinguishing between housing groups is useful, looking at all IHP homes in aggregate also reveals trends. Compared with the Chicagoland housing stock, IHP homes are older than what would be expected from an even sampling of CCS homes. Also, IHP homes represent roughly the same distribution of brick and frame construction as the Chicagoland housing stock. Because some contractors working with IHP specialize in certain housing types, and incentives are offered on a regional basis, aggregating IHP homes in this way is useful because it helps control for these differences that may introduce bias into an energy savings analysis. The IHP data used in this study reflects six Program Providers, 60 contractors, and six different regional rebate structures.

Figure 3 illustrates the spatial distribution of IHP homes in Cook County (n = 267) that fall into the three housing groups that the CCS identified as possessing the greatest cost-effective savings potential: Housing groups 14, 12, and 7. The older frame homes in group 14 are primarily located within the city of Chicago and the “inner-ring” suburbs of Cook County. The newer frame homes in group 12 are primarily located in the suburbs of Cook County, located to the south and northwest of Chicago, farther from the city core than group 14 homes. Group 7 homes are located within Chicago, and they represent nearly two thirds (n = 162) of the total 268 IHP homes in the top three groups. Preliminary analysis did not reveal any abnormal trends in income distribution of IHP homes. Spatial distribution of IHP homes within one region such as this does not impact energy savings; however, it provides useful insight regarding IHP program geographic coverage.

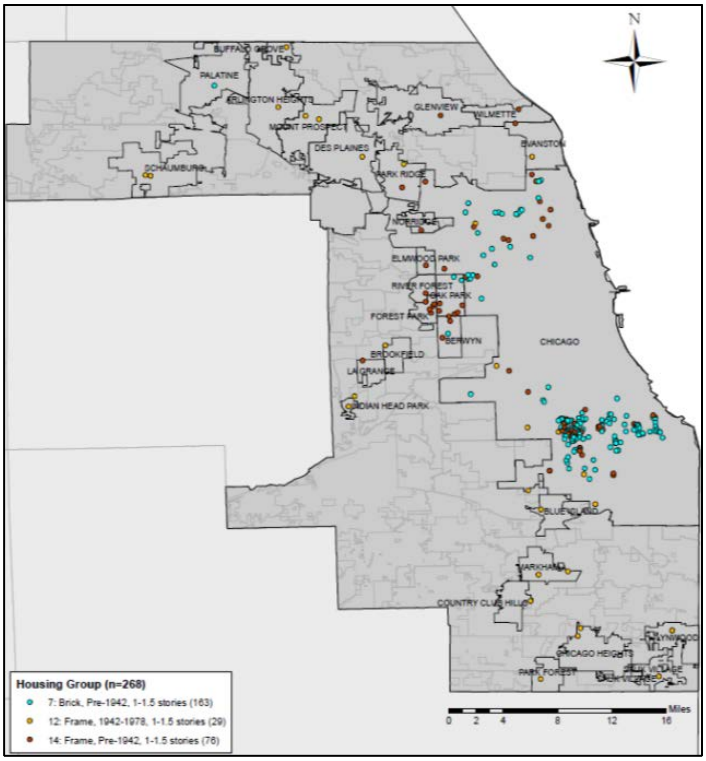

Figure 3. Top three savings potential housing groups: spatial distribution and clustering of IHP participants in Cook County

3.2 Comparing Illinois Home Performance and BEopt Measure Packages

One of the goals of this study is to compare the measures that have been implemented in IHP homes with those recommended as cost-optimal for BEopt. Aggregating field data from homes that have participated in the program help define what measures are commonly installed for each housing group. For comparison, this study relied on previous research that used BEopt existing home retrofit cost-optimization modeling to identify the most cost-effective measures for each housing group; BEopt modeled measures using the housing group characteristics and assumptions identified in the CCS (Spanier et al. 2012). It should be noted that BEopt's default costs assumptions were used to model cost-optimal measure packages; some potential differences between these assumptions and actual measure costs in northern Illinois are discussed later in this report.

Due to small samples sizes in three housing groups, IHP measures were evaluated for 12 out of the 15 housing groups. Air sealing and attic insulation were installed in IHP homes for all 12 housing groups. The most commonly installed measures were, in order of frequency, air sealing, attic insulation, crawlspace insulation, venting exhaust fans to exterior,[2] exterior wall insulation, programmable thermostat installation, furnace replacement, and sealing ducts. A breakdown of all individual housing group measures packages for each housing group can be found in Table 2.

[2] This measure does not impact energy efficiency. It is required by the 2012 International Energy Conservation Code.

Table 2. IHP Measure List

Group	Frame	Year Built	# Stories	Air Sealing	Attic Insulation	Exterior Wall Insulation	Crawlspace Insulation	Exhaust Fans Vented to Exterior	Programmable Thermostat Installed	Furnace Replacement	Ducts Sealed	Total
1	Brick	Post-1978	1–1.5	–	–	–	–	–	–	–	–	–
2	Brick	Post-1978	Split level	–	–	–	–	–	–	–	–	–
3	Brick	Post-1978	2	x	x	–	–	–	–	–	–	2
4	Brick	1942–1978	1–1.5	x	x	–	–	x				3
5	Brick	Pre-1978	Split level	x	x	–	–	–	–	–	–	2
6	Brick	1942–1978	2	x	x	–	–	–	–	–	–	2
7	Brick	Pre-1942	1–1.5	x	x	–	x	x	x	x	x	7
8	Brick	Pre-1942	2	x	x	–	–	–	–	–	–	2
9	Frame	Post-1978	1–1.5	–	–	–	–	–	–	–	–	–
10	Frame	All years	Split level	x	x	–	x	–	–	–	–	3
11	Frame	Post-1978	2	x	x	–	x	–	–	–	–	3
12	Frame	1942–1978	1–1.5	x	x	x	–	–	–	–	–	3
13	Frame	1942–1978	2	x	x	x	x	x	–	–	–	5
14	Frame	Pre-1942	1–1.5	x	x	x	x	x	–	–	–	5
15	Frame	Pre-1942	2	x	x	x	–	x	–	–	–	4
				12	12	4	5	5	1	1	1	

Among the same 12 housing groups, the measures recommended as cost optimal by BEopt, in order of frequency, were air sealing (11 of 12), furnace replacement (9 of 12), attic insulation (8 of 12), and water heater (8 of 12). A breakdown of BEopt-recommended measure packages for each housing group is provided in Table 3.

Table 3. BEopt Recommended Measure Packages by Type

Group	Frame	Year Built	# Stories	Air Sealing	Attic Insulation	Furnace Replacement	Water Heater Replacement	Total
1	Brick	Post-1978	1–1.5	–	–	–	–	–
2	Brick	Post-1978	Split level	–	–	–	–	–
3	Brick	Post-1978	2	x	–	x	–	2
4	Brick	1942–1978	1–1.5	x	–		x	2
5	Brick	Pre-1978	Split level	x	x	x	–	3
6	Brick	1942–1978	2		x	x	x	3
7	Brick	Pre-1942	1–1.5	x	–	x	x	3
8	Brick	Pre-1942	2	x	x	x	x	4
9	Frame	Post-1978	1–1.5	–	–	–	–	–
10	Frame	All years	Split level	x	x	x	x	4
11	Frame	Post-1978	2	x	–	–	x	2
12	Frame	1942–1978	1–1.5	x	x	–	–	2
13	Frame	1942–1978	2	x	x	x	–	3
14	Frame	Pre-1942	1–1.5	x	x	x	x	4
15	Frame	Pre-1942	2	x	x	x	x	4
				11	8	9	8	

There are substantial differences between the measure packages recommended by BEopt and those installed in IHP homes. One of the primary differences is that BEopt's recommendations favored the installation of mechanical equipment, while IHP measures were primarily focused around the building envelope. Also, although air sealing is the most common measure both installed in IHP jobs and recommended by BEopt, the magnitude differs significantly (Table 4). For Table 4, the average post-retrofit infiltration level was calculated by averaging blower door data from actual IHP homes within each housing type. Comparison between IHP and BEopt-recommended infiltration rates indicates that IHP retrofits overwhelmingly experienced greater reductions in infiltration.

Table 4. Post-IHP Retrofit Infiltration Rate

Housing Type	IHP ACH 50	IHP Infiltration	BEopt Infiltration
3	12.0	Typical	Tight
4	9.3	Tight	Typical
5	9.0	Tight	Typical
6	7.0	Tight	No change
7	7.8	Tight	Leaky
8	8.1	Tight	Typical
10	8.1	Tight	Leaky
11	8.1	Tight	Tight
12	8.0	Tight	Typical
13	8.4	Tight	Typical
14	8.4	Tight	Leaky
15	8.6	Tight	Typical

A percentage matching analysis reveals both similarities and differences in measure selection. Figure 4 illustrates the measures recommended by BEopt for housing groups 7, 12, and 14—the three groups the CCS identified as possessing the greatest cost-effective savings potential—and indicates the proportion of IHP retrofits in each housing group that included each particular measure. This figure further demonstrates the infrequency of mechanical equipment measures among IHP retrofits, a trend found throughout all housing groups. At the same time, for these three housing groups, IHP and BEopt match closely on building envelope measures. As stated earlier, IHP retrofits focus heavily on the building shell, including insulation in several areas beyond the attic.

	Air Sealing	*Attic Insulation*	*Efficient Heating* (Furnace/Boiler)	*Efficient Water Heater*
Housing Group 7	**98%** of IHP projects completed this measure	*Not included in BEopt recommended package*	**3%** of IHP projects completed this measure	**0%** of IHP projects completed this measure
Housing Group 12	**100%** of IHP projects completed this measure	**93%** of IHP projects completed this measure	*Not included in BEopt recommended package*	*Not included in BEopt recommended package*
Housing Group 14	**100%** of IHP projects completed this measure	**91%** of IHP projects completed this measure	**5%** of IHP projects completed this measure	**0%** of IHP projects completed this measure

Figure 4. Percentage matching analysis, IHP retrofit measures versus BEopt-recommended measures

3.3 Energy Savings: Illinois Home Performance With ENERGY STAR Versus BEopt Modeling

The measure packages installed by the IHP program and the measures recommended as cost optimal by BEopt were both modeled for their impact on the overall energy savings for each housing group. Evaluation of gas and electricity savings for each housing group type, for IHP measures and for BEopt-recommended measures, indicates that both IHP and BEopt measure packages had a more significant impact on gas savings than electricity savings. With BEopt recommended measures, 3 out of the 12 housing groups experienced greater electric savings and 4 out of 12 housing groups experienced greater gas savings than the IHP measure packages. IHP measure packages reduce energy consumption to a greater degree in more housing groups than BEopt cost-optimized measure packages. IHP gas savings ranged from 1% in housing group 3 to 48% in housing group 12 and exceeded BEopt cost-optimal measures in 8 out of 12 housing groups. BEopt measure package gas savings ranged from 12% in housing group 4 and 41% in housing group 14. IHP electricity savings ranged from –1%[3] in housing group 4 to 7% in housing group 14 and exceeded BEopt cost-optimal measures in 9 out of 12 housing groups (Table 5). BEopt cost-optimal measure's electricity savings ranged from 0% in housing group 7 and 6% in housing group 14 (Table 4). Additional details regarding housing group-level savings data for both BEopt and IHP measure packages can be found in Table 5.

Table 5. Electricity, Gas, and EUI Savings From Baseline Consumption Levels for BEopt and IHP Measures

	Electricity			Gas			EUI		
Group	BEopt (%)	IHP (%)	Δ (%)	BEopt (%)	IHP (%)	Δ (%)	BEopt (%)	IHP (%)	Δ (%)
3	1	0	–1	15	1	–14	9	1	–8
4	1	–1	–2	12	15	2	8	8	0
5	1	3	1	15	17	2	9	12	3
6	1	3	1	18	12	–6	11	8	–3
7	0	1	1	24	24	0	15	15	0
8	3	4	1	30	19	–11	20	13	–7
10	2	3	1	29	26	–3	19	17	–2
11	1	2	1	16	32	16	9	18	9
12	3	4	1	17	24	8	11	16	5
13	3	3	–1	17	28	11	11	17	6
14	6	7	1	41	48	7	28	33	5
15	4	5	2	32	43	11	22	30	8

The magnitude of difference between IHP and BEopt cost-optimal measure packages is significant and varies by housing group (Figure 4). Housing groups with values greater than zero represent homes in which IHP measures resulted in a greater reduction in EUI and housing groups with negative values represent homes in which BEopt measure packages resulted in greater reduction in EUI. Two out of 12 housing groups experienced equivalent EUI reduction, 3 out of 12 housing groups experienced greater EUI reduction with BEopt measures, and 6 out of 12 housing groups experienced greater EUI reduction with IHP measure packages. Figure 4

[3] Increased electricity consumption corresponds directly with exhaust fan electricity consumption.

denotes which housing groups contain brick or frame construction, and also the relative age of the average home in each housing group.

Figure 5. Modeled EUI reduction differences between IHP measures and BEopt-recommended measures

Overall this analysis has shown that IHP measure packages result in greater EUI reduction in frame homes and older homes compared to newer homes and brick homes. This is likely because it is more difficult to insulate the walls in brick homes, and contractors will avoid selecting this measure. It is also possible that frame homes and older homes are more susceptible to issues with air leakage, an issue that IHP addresses frequently. According to the brick home models under the assumptions used, BEopt does not recommend wall insulation as a cost-optimal measure in brick homes.

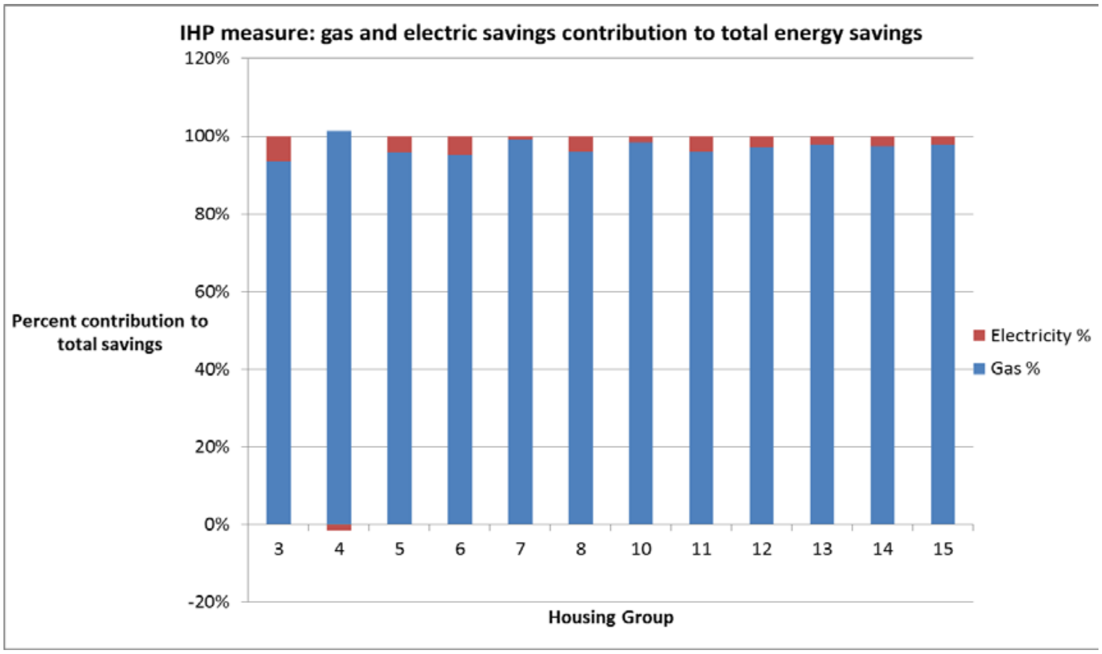

Figure 6. Gas and electricity contributions to total IHP home energy savings

Overall, the measures packages installed during an IHP retrofit result in significantly more gas savings (Figure 4) than electricity savings. In all 12 housing groups analyzed in this study, electricity savings represented less than 10% of the overall energy savings (Figure 4).

3.4 Residential Energy Efficiency Measure Sensitivity Analysis

In addition to evaluating overall energy savings and the differences between IHP and BEopt cost-optimal measure packages, this study also conducted a sensitivity analysis of individual measures to determine the relative magnitude of individual measures on the overall energy reduction. Housing group 7 was chosen for this analysis because it had the largest group of installed measures. The measures that were assessed in this sensitivity analysis are: reducing infiltration, attic insulation, HVAC equipment replacement, crawlspace insulation, mechanical ventilation, programmable thermostat, and duct sealing. Individual residential energy efficiency measures work as a system; however, individual measures may impact the overall energy savings more than others. Measure-level sensitivity analysis demonstrates that the order of impact of energy savings from greatest to least is air sealing, HVAC equipment replacement, programmable thermostat, attic insulation, and then crawlspace insulation (Table 6). The sensitivity analysis has also revealed that duct sealing and mechanical ventilation have a negative impact on overall energy savings. Mechanical ventilation has a negative impact on energy savings because of the electricity required to operate the equipment. This sensitivity analysis helps shed some light on why energy savings differ between IHP measure packages and BEopt measure packages.

Table 6. Sensitivity Analysis of Housing Group 7 Installed Measures

Category	IHP Today	IHP Measure	Savings		
			Energy Savings		Utility Bill Savings ($/year)
			Electricity (kWh)	Gas (therms)	
Infiltration	Very Leaky	Tight	153	209	180
Unfinished Attic	Ceiling R-7 fiberglass, blown-in, vented	Ceiling R-49 fiberglass, blown-in, vented	111	37	38
Furnace/Boiler	Gas, 80% AFUE* Furnace	Gas, 95% AFUE Furnace	–247	200	140
Crawlspace Insulation	Uninsulated	Ceiling R-13, vented	–26	48	37
Mechanical Ventilation	N/A	100% exhaust vented to exterior	–11	–5	(5)
Programmable Thermostat	N/A	Heating setback	430	73	93
Ducts Sealed	N/A	Tight, uninsulated	–36	0	(3)

* Annual fuel utilization efficiency

3.5 Measure Package Cost Analysis

Although cost analysis was not a primary objective of this study, the large differences in measure selection between IHP retrofits and BEopt cost-optimal recommendations warrant investigation. For each housing group, these differences in measure selection strongly influence retrofit cost and energy savings. These two components determine the payback period for the homeowner, a critical and often deterministic feature of retrofits. This study evaluated differences in payback period for the three housing groups with the highest potential for energy savings, groups 7, 12, and 14 (Spanier et al. 2012). BEopt cost data were available for these three housing groups only. Analysis of payback periods for IHP retrofits did not include rebates that are available to IHP homes for individual measures. Table 7 lists the payback period in years for IHP retrofits for each housing group and the payback period in years for BEopt measures for the top three housing groups. The average payback period for IHP measure packages (across all housing groups) was 19 years (10.7 years without an extreme outlier) with a low of 4 years and a high of 110 years.[4] The average payback period for BEopt cost-optimal measure packages was 8.4 years with a low of 7.1 years and a high of 9.8 years (not weighted by housing type or sample size). IHP-installed measures had a longer payback period than BEopt-recommended measures in housing groups 7 and 12 and a shorter payback period in housing group 14. Initial analysis of payback indicates that BEopt-recommended measure packages are more cost effective than IHP-installed measure packages; however, further analysis is required to fully assess cost effectiveness, and future analyses should strive to utilize a more regionally accurate cost library.

[4] The 110-year pack back period is an outlier from the rest of the housing groups. Exclusion of this housing group lowers the average payback to 10.7 years.

Table 7. Measure Package Payback Period: BEopt Cost-Optimal and IHP Measure Packages (years)

	3	4	5	6	7	8	10	11	12	13	14	15
BEopt					9.8				8.2		7.1	
IHP	110.0	22.2	12.9	16.0	11.5	9.3	5.8	13.2	9.5	8.8	4.6	4.0

Table 8 lists the average total retrofit costs for BEopt-recommended cost-optimal measures, pre-rebate IHP-installed measures, and pre-rebate IHP-installed measures as modeled by BEopt. Because BEopt software selects measures that maximize cost effectiveness and will not select measures that negatively impact overall cost effectiveness, the fact that actual IHP-installed measure costs and BEopt-recommended measure costs are similar indicates that IHP-installed measure packages cost close to what is deemed to be optimal by BEopt. Using BEopt to model actual IHP retrofit measures generated costs that are significantly higher than actual retrofit costs (Table 8). BEopt costs were drawn from the National Residential Efficiency Measures Database. This discrepancy is important because it indicates that BEopt measure cost assumptions are different than actual market costs available to IHP participants. However, even knowing that these costs could not be exactly compared, this study still examines the magnitude of differences between housing groups as a way to gain insight into potential trends. Future research should examine why these costs differ by such a wide margin, and revision of the cost library used will lead to more accurate analyses. Going forward, program administrators using this methodology to evaluate cost effectiveness must be sure to carefully identify measure cost information.

Table 8. Measure Package Cost: BEopt Cost-optimal, IHP, and IHP Measures Modeled by BEopt (in dollars)

	3	4	5	6	7	8	10	11	12	13	14	15
BEopt	–	–	–	–	3,160	–	–	–	2,035	–	4,808	–
IHP	2,492	3,695	3,484	3,668	3,832	3,652	3,160	4,186	3,795	3,440	3,669	3,566
IHP via BEopt	–	–	–	–	11,433	–	–	–	9,954	–	12,255	–

4 Discussion

There is a significant gap between what is actually being done in the field and what was identified as cost optimal through BEopt modeling. These differences have resulted in significant modeled energy reduction values between both scenarios. One potential reason involves air sealing actions; for each housing group and under the cost assumptions used, BEopt recommended to tighten homes one step only, e.g., from very leaky to leaky. Future analysis of why this was recommended would be helpful. IHP data show that in the field, air infiltration reduction can move several steps. The results of this research have also shed light on how well the IHP program has targeted the existing Chicagoland housing stock. The following discussion will explore how the results of this research impact utility energy efficiency program applications of building science, whole-home energy efficiency retrofit programs, and the IHP program.

In the future, modeling cost effectiveness should attempt to incorporate factors that impact cost decisions. Previous research touched on this; however, because this study focused on defining a methodology for analyzing energy use in housing archetypes, the authors did not take steps to identify and input custom cost assumptions. One way that incorporating more regionally accurate costs into modeling assumptions can benefit future research is that a reduction in measure cost, caused by a rebate for example, may affect exactly what is deemed cost effective (see Baker et al. [2013] for related discussion). Rebates are available for multiple IHP measures; however, the reduction in cost has not been incorporated in the BEopt modeling. Future cost-benefit measure-selection analysis should incorporate real-world rebates so that what is modeled as cost optimal incorporates measure costs identical to what is found in IHP qualifying homes.

4.1 Research Questions

How do modeled optimal energy savings for each housing type compare to the energy savings derived from typically installed measure packages for that housing type?

Modeled optimal energy saving for each housing type varies from what is typically installed during IHP retrofits. In general, this analysis has shown that IHP measure packages result in greater EUI reduction in frame homes and older homes.

How many homes have participated in IHP for each of the 15 housing types?

When this study was written, 503 of the first 800 IHP homes were able to be characterized into a housing type. Table 6 lists the breakdown of IHP homes into each individual housing group.

Table 9. Number of IHP Homes in Each Housing Archetype

Housing Type	Number of Homes	% of Total
1	1	0.2
2	1	0.2
3	5	1
4	57	11.2
5	7	1.4
6	25	5
7	162	32.2
8	20	4
9	0	0
10	15	3
11	18	3.6
12	29	5.6
13	37	7.4
14	76	15.2
15	50	10

What are the characteristics of retrofits currently occurring under the IHP program platform in northern Illinois?

The retrofit characteristics currently occurring under the IHP program differ between each housing group; however, the top measures include air sealing, attic insulation, exterior wall insulation, crawlspace insulation, and mechanical ventilation.

What measure packages are commonly installed for each of the 15 housing types?

The most common measures installed in all housing types are air sealing and attic insulation. A detailed list of common measures for each housing group can be found in Table 2.

What is the missed energy savings opportunity resulting from not installing cost-optimal measures?

The majority of housing groups did not save more energy when the BEopt-identified cost-optimal measures packages were installed. Only four housing groups experienced a greater reduction in energy consumption by installing measures identified as cost optimal. Additionally, initial analysis of economic payback indicates that BEopt-recommended measure packages are more cost effective than IHP-installed measure packages; however, further analysis is required to fully assess cost effectiveness.

How do large datasets help explain homeowner decision-making behavior and energy savings objectives?

Large datasets are important because they can help identify trends in retrofit measure selection. Large datasets have allowed this study to identify trends in what measures are typically being installed and what opportunities exist to maximize the energy savings across the Chicagoland area.

What housing types should existing programs focus on to provide maximum cost-effective energy savings?

Existing programs should focus on housing groups 7, 12, and 14. These programs represent a significant portion of the Chicagoland housing stock and a significant opportunity for energy savings.

4.2 General Programmatic Impacts

This study's findings and evaluation methodology have significant relevance to whole-home retrofit programs nationwide. Many of the results presented in this study are relevant only to the climactic conditions and home construction practices of northern Illinois, but the decision-making and energy savings associated with retrofit measure selection are transferable to other climates and whole-home retrofit programs. One of the primary transferable conclusions of this study is that home categorization may help reduce some of the time and energy that goes into home energy audits. Specifically, development of an optimal portfolio of retrofit measures for each house may allow contractors and auditors to draw upon what has been done in the past to quickly recommend what should be done for each specific housing group. Establishment of minimum recommended measures for each housing type will allow home performance contractors to quickly recommend optimal measures. Streamlining the whole-home retrofit process will eventually serve to reduce the overall transaction costs between the homeowner and the contractor. This study has shown, however, for most housing archetypes, substantial differences can exist between modeled cost and savings and actual cost and savings. Because the cost assumptions used here were likely not tailored enough to regional differences and available rebates, future research should recognize that accurate cost information is critical to proper evaluation. Perhaps the best approach is to make programmatic decisions only after both types of analysis.

Another transferable lesson is that early evaluation of a whole home program's sampling and individual measure selection can help provide valuable programmatic feedback. Analysis of how a program is sampling a geographic location's housing population can help identify potential areas or housing group populations that are being underrepresented or overrepresented. Correlating this analysis to housing-group level differences in energy savings potential can also help identify opportunities to maximize energy savings potential and programmatic effectiveness. Analysis of the individual measures can help verify that the measures actually being installed are achieving the optimal level of energy savings. If the analysis finds that measures identified as cost-optimal are not being installed the program's focus can be redirected towards what is deemed to be the most cost-optimal measures. The methodology presented in this study should be valuable to other whole-home retrofit programs and can help provide valuable programmatic feedback to program managers and energy efficiency policy makers.

4.3 Illinois Home Performance-Specific Impacts

Overall, the distribution of IHP homes across housing groups roughly matches that of the Chicagoland housing stock, with housing groups 7 and 12 being exceptions. Although IHP welcomes all housing types, locations, and income levels to participate in the program, housing group 7 was greatly oversampled due to a productive program partner focusing specifically on the traditional Chicago bungalow, which is characterized as housing group 7. This provides a good example of how the focus of a retrofit program can drift toward a particular location, housing type, income level, or set of measures despite maintaining openness to all of these attributes.

Comparing the population distribution of IHP with the total area housing stock assists in identifying gaps in IHP participation, areas of program underrepresentation, and potential for greater overall energy savings. More specifically, looking at both EUI reduction potential and a total housing group population together can identify areas that may yield the greatest overall regional energy savings. Using this method, the CCS identified housing groups with the greatest potential for energy savings through BEopt-recommended retrofits: Housing groups 7, 12, and 14 (Spanier et al. 2012).

Figure 2 clearly shows that IHP is succeeding at retrofitting homes in housing groups 7 and 14; however, homes in housing group 12 are in need of more attention from the program. The small sample size in this housing group receiving IHP recognition may be due to socioeconomic factors such as limiting homeowner incomes or spatial mismatch between homes and program marketing. This study has shown that the IHP program can have significant savings in housing group 12; therefore, this underrepresented housing group represents significant energy savings opportunity. Further investigation into how the program can more consistently reach these homes is warranted.

Also interesting is the apparent effectiveness of the measure packages installed in IHP homes with frame construction. As discussed above, this is likely a result of numerous building envelope measures such as air sealing and insulation. The high levels of EUI reduction due to IHP measure packages in frame homes—and lower levels in brick homes—suggest that if the program maintains its current focus on envelope improvements, it may want to focus more on frame homes in order to maximize the program's overall impact on energy savings. Alternatively, because IHP measure packages in brick homes are underperforming compared to BEopt-recommended measure packages, program incentives could be revised to encourage measure packages that more closely match BEopt cost-optimal packages.

Also apparent is the large thematic difference between IHP-installed measures and BEopt-recommended measures. In general, BEopt frequently recommends mechanical equipment upgrades, while IHP retrofits focus more heavily on envelope improvements. The IHP program should further investigate the feasibility of encouraging the upgrade of water heaters and other heating systems. In particular, these equipment upgrades may garner more savings in homes with brick construction, whereas building envelope improvements face more challenges than with frame homes.

4.4 Building Science Impacts

Analysis of the measures installed in IHP homes and recommend by BEopt cost optimization software has revealed important differences in measure selection. This study has found that, in the majority of housing groups, the measure packages common to the IHP program result in a greater reduction in energy consumption than measures that have been recommended by BEopt. Specifically, this study has found that reducing infiltration through air sealing and heat loss through attic insulation has a significantly greater impact than BEopt modeled results. This result is important because it reinforces the current program framework and incentive packages offered by program providers.

Every effort was made to generate BEopt cost-optimal recommendations and to model actual IHP measure packages under the same assumptions; however, there were several assumptions and limitations that confound the modeling software's measure selection. One of the primary differences between IHP contractor measure selection and BEopt measure selection is that IHP contactors are required to comply with the 2012 International Energy Conservation Code for impacted measures (e.g., attic insulation must be brought up to code if the attic insulation is to be improved). Exact requirements of the Illinois version of the code are listed in Appendix B. Existing energy code impacts both what is installed in IHP homes and what is not recommended by BEopt. For instance, during IHP measure selection, contactors may install a measure (attic insulation) to a level that goes beyond cost optimal, and during BEopt measure selection, the software may install a measure only to the point at which it is deemed cost effective. Future applications where in-field measure selection is compared with cost-optimized measure selection should incorporate limiting factors such as local building codes and should look at cost optimization not only as an optimal point, but also as a series of near neighbors on a curve that can be viewed together. Incorporating real-world influences that impact what is actually installed will refine and strengthen future comparisons between program measure data and cost-optimized measure data.

Analysis of payback and relative cost effectiveness of IHP-installed and BEopt-recommended measure packages reveals the economic impact of differing residential energy efficiency retrofit measure packages. The cost effectiveness results presented in this study are not conclusive, but do suggest that the measure packages commonly installed during IHP retrofits in many housing groups can be as cost effective as measure packages deemed cost optimal by BEopt. Payback and cost effectiveness metrics cannot be used to evaluate overall program efficacy because they are a function of both absolute energy savings and total retrofit cost; therefore, the magnitude of energy savings and of total measure package costs should be viewed independently to satisfy programmatic goals other than economic utility.

Additionally, the use of BEopt modeling software to model cost optimization has revealed that BEopt's cost assumptions generate significantly higher total measure package costs than what are being observed during actual retrofits. In order to accurately model cost optimality, researchers must use BEopt software in a way that reflects actual market conditions and retrofit measure costs. Future research should work to share actual residential energy efficiency retrofit measure cost data so that BEopt can ensure that its cost assumptions are accurate.

4.5 Directions for Future Research

Further research is needed to update the CCS BEopt models to match the International Energy Conservation Code insulation levels and air infiltration reduction levels found in the field data and consider other common upgrades by Group. Also, further work is needed to examine and compare the costs of both BEopt recommended measures and IHP common measures. Preliminary assessment of BEopt measure package costs and IHP measure package costs reveals that there is a significant cost difference between the two measure packages. Specifically, BEopt cost-optimal measures cost more than IHP measure packages. If possible, future research should incorporate real-world rebate levels, into the building science modelling software, to control for the cost differences between what is being modelled and what is actually occurring. In-depth cost analysis was not included in this research, but such an analysis would likely yield key lessons for both program administrators as well as BEopt users. The results of this study can also be used to further refine and improve upon the assumptions that were originally made in the CCS study. Refinement of the original characterization assumptions is important because it can help assure that the original characterization and recommended measure packages are accurate and depict actual housing stock characteristics.

5 Conclusion

This project compared the energy savings potential of common IHP measure packages and BEopt cost-optimized measure packages. This research builds upon previous work by analyzing data from the first 800 homes to receive IHP recognition. Evaluation of the IHP measure packages was based on the actual retrofit measure selection, Chicagoland single-family housing group archetype demographics,[5] and BEopt modeling software. Comparison between the actual measures installed in IHP homes and BEopt recommended measures indicate that for most housing groups, there are substantial differences in measure selection. Overall, IHP measure packages result in greater EUI reduction in frame homes and older homes. Measure packages installed during an IHP retrofit also result in significantly more gas savings than electricity savings, as compared to measure packages recommended as cost optimal by BEopt.

The methodology and findings of this study are important in that they provide valuable feedback for the current IHP program and guidance for other whole-home retrofit programs seeking to self-evaluate using large data sets. This study supports the hypothesis that archetyping can be used to link housing type to standardized retrofit measure packages and streamline the process for single-family home energy retrofits to maximize both energy savings and cost effectiveness.

[5] Housing characterization is based on the CCS study.

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Appendix A: Illinois Home Performance Measures

Group	Category	TO2		TO3	
		BEopt Today	BEopt Upgrade	IHP Today	IHP Upgrade
3	Infiltration	Typical	Tight	Leaky	Typical
	Unfinished Attic	Ceiling R-38 fiberglass batts, vented	No change	Ceiling R-38 fiberglass batts, vented	Ceiling R-49 fiberglass batts, vented
	Furnace/Boiler	Gas, AFUE 80%, furnace	No change	Gas, AFUE 80%, furnace	No change
	Water Heater	Gas 0.54 EF	Gas premium 0.67 EF	Gas 0.54 EF	No change
4	Infiltration	Leaky	Typical	Leaky	Tight
	Unfinished Attic	Ceiling R-19 fiberglass blown-in, vented	No change	Ceiling R-19 fiberglass blown-in, vented	Ceiling R-49 fiberglass blown-in, vented
	Furnace/Boiler	Gas, AFUE 78%, furnace	No change	Gas, AFUE 78%, furnace	No change
	Water Heater	Gas 0.54 EF	Gas premium 0.67 EF	Gas 0.54 EF	No change
	Mechanical Ventilation	Spot vent only	No change	Spot vent only	100% exhaust vented to exterior
5	Infiltration	Leaky	Typical	Leaky	Tight
	Unfinished Attic	Ceiling R-19 fiberglass blown-in, vented	Ceiling R-38 fiberglass blown-in, vented	Ceiling R-19 fiberglass blown-in, vented	Ceiling R-49 fiberglass blown-in, vented
	Furnace/Boiler	Gas, AFUE 78%, furnace	Gas, AFUE 92.5%, furnace	Gas, AFUE 78%, furnace	No change
6	Infiltration	Typical	No change	Typical	Tight
	Unfinished Attic	Ceiling R-19 fiberglass blown-in, vented	Ceiling R-38 fiberglass blown-in, vented	Ceiling R-19 fiberglass blown-in, vented	Ceiling R-49 fiberglass blown-in, vented
	Furnace/Boiler	Gas, AFUE 78%, furnace	Gas, AFUE 92.5%, furnace	Gas, AFUE 78%, furnace	No change
	Water Heater	Gas 0.54 EF	Gas premium 0.67 EF	Gas 0.54 EF	No change
7	Infiltration	Very leaky	Leaky	Very leaky	Tight
	Unfinished Attic	Ceiling R-7 fiberglass blown-in, vented	No change	Ceiling R-7 fiberglass blown-in, vented	Ceiling R-49 fiberglass blown-in, vented
	Furnace/Boiler	Gas, AFUE	Gas, AFUE	Gas, AFUE	Gas, AFUE 95%,

Group	Category	TO2		TO3	
		BEopt Today	BEopt Upgrade	IHP Today	IHP Upgrade
		80%, boiler	92.5%, boiler	80%, boiler	furnace
	Water Heater	Gas 0.54 EF	Gas premium 0.67 EF	Gas 0.54 EF	No change
	Crawlspace Insulation	None	None	Uninsulated	Ceiling R-13, vented
	Mechanical Ventilation	None	None	None	100% exhaust vented to exterior
	Programmable Thermostat Installed	None	None	None	Heating set 70°F with setback 65°F; Cooling set 72°F
	Ducts Sealed	None	None	None	Tight, uninsulated
8	Infiltration	Leaky	Typical	Leaky	Tight
	Unfinished Attic	Ceiling R-7 fiberglass blown-in, vented	Ceiling R-30 fiberglass blown-in, vented	Ceiling R-7 fiberglass blown-in, vented	Ceiling R-49 fiberglass blown-in, vented
	Furnace/Boiler	Gas, AFUE 80%, boiler	Gas, AFUE 95%, boiler	Gas, AFUE 80%, boiler	No change
	Water Heater	Gas 0.54 EF	Gas premium 0.67 EF	Gas 0.54 EF	No change
10	Infiltration	Leaky	Leaky	Very Leaky	Tight
	Unfinished Attic	Ceiling R-7 fiberglass blown-in, vented	Ceiling R-38 fiberglass blown-in, vented	Ceiling R-7 fiberglass blown-in, vented	Ceiling R-49 fiberglass blown-in, vented
	Furnace/Boiler	Gas, AFUE 80%, boiler	Gas, AFUE 95%, boiler	Gas, AFUE 80%, boiler	No change
	Water Heater	Gas 0.54 EF	Gas premium 0.67 EF	Gas 0.54 EF	No change
	Crawlspace Insulation	None	None	Uninsulated	Ceiling R-14, vented
11	Infiltration	Typical	Tight	Typical	Tighter
	Unfinished Attic	Ceiling R-38 fiberglass batts, vented	No change	Ceiling R-38 fiberglass batts, vented	Ceiling R-49 fiberglass blown-in, vented
	Furnace/Boiler	Gas, AFUE 80%, furnace	No change	Gas, AFUE 80%, furnace	No change
	Water Heater	Gas 0.54 EF	Gas premium 0.67 EF	Gas 0.54 EF	No change
	Crawlspace Insulation	None	None	Uninsulated	Ceiling R-14, vented
12	Infiltration	Leaky	Typical	Leaky	Tight

Group	Category	TO2		TO3	
		BEopt Today	BEopt Upgrade	IHP Today	IHP Upgrade
	Unfinished Attic	Ceiling R-19 fiberglass blown-in, vented	Ceiling R-49 fiberglass blown-in, vented	Ceiling R-19 fiberglass blown-in, vented	Ceiling R-49 fiberglass blown-in, vented
	Furnace/Boiler	Gas, AFUE 78%, furnace	No change	Gas, AFUE 78%, furnace	No change
	Exterior Wall Insulation	R-7	No change	R-7	R-13
13	Infiltration	Leaky	Typical	Leaky	Tight
	Unfinished Attic	Ceiling R-19 fiberglass blown-in, vented	Ceiling R-38 fiberglass blown-in, vented	Ceiling R-19 fiberglass blown-in, vented	Ceiling R-49 fiberglass blown-in, vented
	Furnace/Boiler	Gas, AFUE 78%, furnace	Gas, AFUE 92.5%, furnace	Gas, AFUE 78%, furnace	No change
	Water Heater	Gas 0.54 EF	No change	Gas 0.54 EF	No change
	Crawlspace	None	None	Uninsulated	Ceiling R-14, vented
	Mechanical Ventilation	Spot vent only	No change	Spot vent only	100% exhaust vented to exterior
	Exterior Wall Insulation	R-7	No change	R-7	R-13
14	Infiltration	Very leaky	Leaky	Very leaky	Tight
	Unfinished Attic	Floored R-3 roof insulation unvented	Ceiling R-38 fiberglass blown-in, vented	Floored R-3 roof insulation	Ceiling R-49 fiberglass blown-in, vented
	Furnace/Boiler	Gas, AFUE 80%, furnace	Gas, AFUE 95%, furnace	Gas, AFUE 80%, furnace	No change
	Water Heater	Gas 0.54 EF	Gas premium 0.67 EF	Gas 0.54 EF	No change
	Crawlspace	None	None	Uninsulated	Ceiling R-14, vented
	Mechanical Ventilation	Spot vent only	No change	Spot vent only	100% exhaust vented to exterior
	Exterior Wall Insulation	Uninsulated	Uninsulated	Uninsulated	R-13
15	Infiltration	Leaky	Typical	Leaky	Tight
	Unfinished Attic	Ceiling R-7 fiberglass blown-in, vented	Ceiling R-38 fiberglass blown-in, vented	Ceiling R-7 fiberglass blown-in, vented	Ceiling R-49 fiberglass blown-in, vented
	Furnace/Boiler	Gas, AFUE	Gas, AFUE	Gas, AFUE	No change

Group	Category	TO2		TO3	
		BEopt Today	BEopt Upgrade	IHP Today	IHP Upgrade
		80%, boiler	95%, boiler	80%, boiler	
	Water Heater	Gas 0.54 EF	Gas premium 0.67 EF	Gas 0.54 EF	No change
	Crawlspace	None	None	Uninsulated	Ceiling R-14, vented
	Mechanical Ventilation	Spot vent only	No change	Spot vent only	100% exhaust vented to exterior
	Exterior Wall Insulation	Uninsulated	Uninsulated	Uninsulated	R-13

Appendix B: 2012 International Conservation Code with Illinois Amendments

Requirements by Component	2012 Illinois Code
Fenestration U-Factor	0.32
Skylight U-Factor	0.55
Glazed Fenestration SHGC	NR
Ceiling R-Value	R-49
Wood Frame Wall R-Value	20 or 13 + 5
Mechanical Ventilation	ASHRAE 62.2
Basement/Crawlspace R-Value	15/19, insulation down 4 ft
Thermal Envelope Testing	Requires blower door test < 5 ACH50
Floor R-Value	R-30
Eave Baffle	Requirement
Wood-Burning Fireplace	Tight-fitting flue dampers
Duct Insulation	R-6, in attic 4-8
Duct Leakage Requirements	4 cfm25/100 ft^2
Building Cavities	Not use as ducts or plenums
Mechanical System Piping Insulation	R-3
Hot Water Piping Insulation	R-3
Equipment Sizing	ACCA Manuals S and J
Lighting Equipment	Minimum 75% high efficiency

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