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Chicagoland Single-Family Housing Characterization

J. Spanier, R. Scheu, L. Brand, and J. Yang
Partnership for Advanced Residential Retrofit (PARR)

June 2012

Building America
U.S. Department of Energy

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Unless otherwise noted, all figures were created by the PARR team.

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Unless otherwise noted, all tables were created by the PARR team.

Definitions

BRC	Building Research Council at the University of Illinois, a member of the Partnership for Advanced Residential Retrofit
BTU	British Thermal Unit is a unit of heat. 100,000 BTU equal 1 therm.
CDD	Cooling Degree Days
CNT	Center for Neighborhood Technology, an implementer of the proposed plan, currently running a portfolio of energy efficiency programs
DOE	U.S. Department of Energy, a sponsor
EUI	Energy Use Intensity is a standardized comparison for benchmarking buildings, measured in kBtu per ft^2 per year
FutEE	Future Energy Enterprise, a member of the Partnership for Advanced Residential Retrofit
GTI	Gas Technology Institute, an implementer
HDD	Heating Degree Days
MEEA	Midwest Energy Efficiency Alliance, a member of the Partnership for Advanced Residential Retrofit
MEL	Miscellaneous Electrical Load
PARR	Partnership for Advanced Residential Retrofit, a Building America team led by the Gas Technology Institute
RECS	Residential Energy Consumption Survey
TO	Task Order, referring to a time dependent work order

Executive Summary

In this project, the PARR team identifies housing characteristics and energy use for fifteen single-family housing types (groups) in the Chicagoland region and specifies measure packages that provide an optimum level of energy savings based on a BEopt analysis. In its research, the team used property assessor data and actual energy consumption of 432,605 houses representing approximately 30% of the single-family home population. The optimum package of energy efficiency measures developed is based on a target of cost effectiveness at the measure level and 30% source energy savings. Based on the BEopt result, the project identifies the three housing groups that provide the maximum energy savings potential as defined by annual source energy savings multiplied by the total number of houses in the sample population. The three groups based on construction characteristics (structural, vintage and size) and identified as having the greatest potential as a result of this analysis are:

1. Wood frame, pre-1942 construction, 1 to 1.5 stories
2. Brick (double brick), pre-1942 construction, 1 to 1.5 stories
3. Wood frame, 1942-1978 construction, 1 to 1.5 stories.

These three housing groups will be used in the next step in the project to evaluate the measure packages. The PARR team will work with installing contractors in the field to document the upgrades that have been done to the houses since they were built, determine the cost of performing the proposed set of upgrades, and identify techniques that can be used for low-cost implementation on a community scale.[1]

Homeowners and efficiency program implementers require meaningful peer groups and benchmark comparisons in order to make informed upgrade decisions, and to use realistic savings estimates based on performance of a large population of similar homes of comparable size, vintage, and construction.

The segmentation methodology presented in this report is intended to be replicable in other parts of the country. Each region has varying yet distinct home characteristics (construction type, vintage and size), weather and energy regulatory environments that influence how much energy a home consumes, and upgrades that can offer the greatest energy savings. Coupling housing segmentation with measured energy data analysis for a large population of homes reduces the effect of outliers, and can significantly reduce program costs by eliminating the need for modeling each individual similarly constructed home. This replicable approach can dramatically impact how broad-scale retrofit implementation programs are developed, implemented, and brought to scale.

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[1] Peters, Jamie, EE Solution Package for Top 3 Housing Types – Field Tests from Chicagoland Housing (to be issued later in 2012)

1 Introduction and Background

1.1 Introduction

This project identifies housing characteristics and energy use for common homes in the Chicagoland region and produces advanced efficiency measure packages that can be implemented in the region's existing homes. The term "Chicagoland" is defined in this report as the city and the suburbs that make up Cook County, Illinois. Three housing types will be selected that show the best opportunity for energy savings using BEopt modeling of potential energy efficiency package options, with a target of 30% source energy savings. This savings is equivalent to between $600 and $750 per home per year.

The U.S. Department of Energy's (DOE) Building America program focuses on conducting research to improve the efficiency of new and existing homes. The program's overall goal is to develop integrated systems solutions that can take advantage of economies of scale.

The Partnership for Advanced Residential Retrofit (PARR) is a Building America team based in Chicago, researching energy efficiency solutions for residential housing with a focus on cold climate retrofits in the Midwest. PARR, led by GTI, represents a broad spectrum of residential building stakeholders including CNT Energy, Midwest Energy Efficiency Alliance (MEEA), Building Research Council at the University of Illinois (BRC), and Future Energy Enterprise (FutEE). These stakeholders are critical to designing, executing, and disseminating impactful research. PARR possesses strong experience in design, development, integration, and testing of advanced building energy equipment. PARR applies this experience in testing components and systems in laboratory and test house settings to improve performance, quality, and market acceptance of whole house residential energy efficiency retrofits in cold climates.

PARR was expressly created to make residential energy efficiency retrofits more cost effective and to demonstrate concepts that enable market transformation on a mass scale. PARR aims to increase the quality and uptake of residential retrofits in the midwest United States while providing Building America with systems, whole home, and community level solutions for the entire cold climate region.

Toward this goal, PARR is performing a characterization of the top fifteen housing types (groups) in Chicagoland based on assessor data, utility billing history, and available data from prior energy efficiency programs. PARR will analyze the data and recommend the housing types to focus on for designing retrofit packages using cost effectiveness of energy savings for ranking. Following this, PARR will use BEopt modeling software, paired with local cost data, to design retrofit packages for the three building types to be implemented in the field by local contractors under another PARR project

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1.2 Background

There are more than 3.3 million single-family homes in the seven-county Chicagoland area, which represents 63% of the population of the single-family homes in Illinois. This research focuses on Cook County, the most housing-dense county in the region, where there are nearly 2 million households and 1.1 million single-family homes. The median built year of the single-family housing stock is 1956, prior to implementation of energy codes requiring the installation of insulation. The region's extreme weather - long, cold winters and shorter hot, humid summers - combined with the older housing stock, makes homes in this region very energy intensive (nearly twice the national average), with heating being the dominant energy expenditure.

As energy costs increase, home energy improvements have the potential to keep housing affordable, improve comfort, and preserve the existing housing stock. There is significant need for cost-effective retrofit solutions that can be deployed at scale. Improving the efficiency of the region's housing can save homeowners money, improve the workforce, and strengthen the local economy. This project will identify which housing types to target and what retrofit packages offer the most cost effective energy savings.

The single-family housing stock in Cook County consists of varying types, many dating back before the Great Chicago Fire of 1871. There are more than a dozen housing types, and a dominant one is the iconic Chicago bungalow. The bungalow is a deep single-story structure with narrow street exposure, high-pitched roof, and a dormered attic space that is often converted to additional living space. Nearly 80,000 bungalows were built in the region between 1910 and 1940. These homes share similar construction features and they are ubiquitous in the region, with many blocks in neighborhoods described as part of a 'bungalow belt.' As a group, bungalows consume approximately 25% more energy per square foot than the median home in the region, and represent huge energy savings potential. Because of their similarity, bungalows tend to require similar retrofit upgrades, such as attic air sealing and insulation. The bungalow is an example of how prescriptive retrofit packages can be customized to a specific housing type.

1.3 History of Chicago Buildings

The city of Chicago began as a settlement at the mouth of the Chicago River at Lake Michigan in the 1780's. Illinois reached statehood in 1818, and the city of Chicago was officially incorporated in 1832, followed by rapid growth. The great Chicago fire of 1871 destroyed the central business district and 18,000 buildings including one-third of all the residential structures. Strict building codes were instituted following the fire, favoring solid masonry construction in most commercial buildings and a large percentage of single-family and multifamily buildings well into the next century. The bungalow building era was at the center of the building boom of the early 1900's, and the current single-family building stock is significantly influenced by the construction boom in that era. Pre-1942 uninsulated wood frame and solid masonry buildings are the predominant type of construction, offering many challenges for energy efficiency retrofits.

According to 2010 U. S. census data, Cook County has a population of 5.2 million people occupying 2.2 million dwelling units. Multifamily housing accounts for 54% of the county's housing units, leaving 1.1 million single-family dwellings as the focus of this study.

1.4 Relevance to Building America's Goals

"The goal of the U.S. Department of Energy's (DOE) Building America program is to conduct research to develop market-ready energy solutions that improve efficiency of new and existing homes in each U.S. climate zone, while increasing comfort, safety, and durability."[2]

[2] http://www1.eere.energy.gov/buildings/building_america/program_goals.html

To develop retrofit packages geared towards homes in the Chicagoland region, it is essential to know more about the structural and energy use characteristics of the homes. As a colder humid continental climate, Chicago has an average of roughly 6,500 HDD and 800 CDD. Heating is the dominant energy end use, and heat load reduction typically offers the most energy-savings potential in this region.

Part of the motivation behind this project is to increase the visibility and use of large datasets to inform program decisions and retrofit activities. These goals naturally increase the scalability of retrofits, and would serve the larger goal of increased data and knowledge about the energy use of the residential building stock in the Chicago region. This work will also provide program decision-makers with information for targeting the most cost-effective housing types in terms of energy upgrades, improving performance of public dollars and heightening the value proposition for property owners.

Further motivation is based on the rollout of Home Performance with ENERGY STAR in Illinois. This project will provide the outline of retrofit packages by home types to be used as guidance for contractors taking homes through the program.

1.5 Cost Effectiveness

"Many energy efficiency programs rely on energy assessments that can cost $100 to $600 to identify the energy saving improvements for each participating household. A less costly option is to forego an onsite home assessment, and use prescriptive approaches, offering a standard set of measures that are widely expected to save energy across a range of properties or within a specific type of targeted housing."[3]

Large datasets help to reduce the transaction costs of analyzing and retrofitting a home. The ability to describe both the structural characteristics and energy use of a population of homes helps homeowners, assessors, contractors and policymakers make informed decisions regarding residential energy efficiency.

In addition, the data will enable modeling of a population of homes. Although customization of retrofit packages is required to retrofit an individual home, being able to do the first run of a model using data based on the population cuts down on the costs needed to model individual homes. It also enhances ability of marketers and related stakeholders to design programs that target buildings with the most potential for cost-effective energy savings.

Although the costs and savings associated with retrofitting individual homes will vary greatly depending on the measures administered to particular subjects in the sample, the retrofit packages will be cost effective as applied to the population of similar homes.

1.6 Tradeoffs and Other Benefits

The energy benchmarks for home types created from this research will aid in market transformation; a home with lower energy use or more potential for energy upgrades can be valued more than a comparable home without those attributes.

[3] Delivering Energy Efficiency to Middle Income Single Family Households," Zimring et al. Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, December 2011.

In addition, these data can be used as reference for program design of future energy efficiency programs. While not included in the scope of this research, the data available can be used to spatially identify clusters of high energy use and inform targeted program design of certain geographies or communities. Through this type of characterization, it may be possible to offer energy upgrades to groups of homes without an audit; understanding from the typical energy signature how the building is built, what measures have likely already been applied, and which upgrades are cost effective going forward.

2 Objective

The objective of this project is to identify which of the 15 housing types (groups) to target and what retrofit packages to apply for cost-optimized energy savings that will have the largest impact in the region.

The PARR team intends to compare buildings on all of these dimensions simultaneously.

The research questions to be addressed in this project are as follows:

What are the most common housing types in Cook County?

What are the energy use characteristics of these housing types?

Can large datasets be used to identify cost-effective retrofit opportunities?

What are the types of housing to target for retrofit packages?

Do identified databases provide sufficient detail for modeling inputs?

What housing characteristics are most significant toward determining cost effectiveness of retrofit?

What is the relationship between housing type energy intensity and potential cost-effective energy savings?

3 Approach

The approach to this project consists of four elements and the activities within each element:

- Data collection
- Data cleaning and manipulation
- Development of housing groups
- BEopt modeling.

A discussion of each element is provided in the subsections below.

3.1 Data Collection

The research team gathered data from the three utilities serving the Chicago metropolitan region[4]. ComEd, the electric utility for northern Illinois, provided data for all residential accounts by address, including monthly kWh usage data. Integrys, the owner of People's Gas in Chicago and North Shore Gas in parts of Cook and Lake Counties, provided data for all residential accounts by address, including monthly therms usage data. Nicor Gas, the natural gas utility for northern Illinois minus the territory covered by Integrys, provided data for all residential accounts by address, including annual therms usage data.

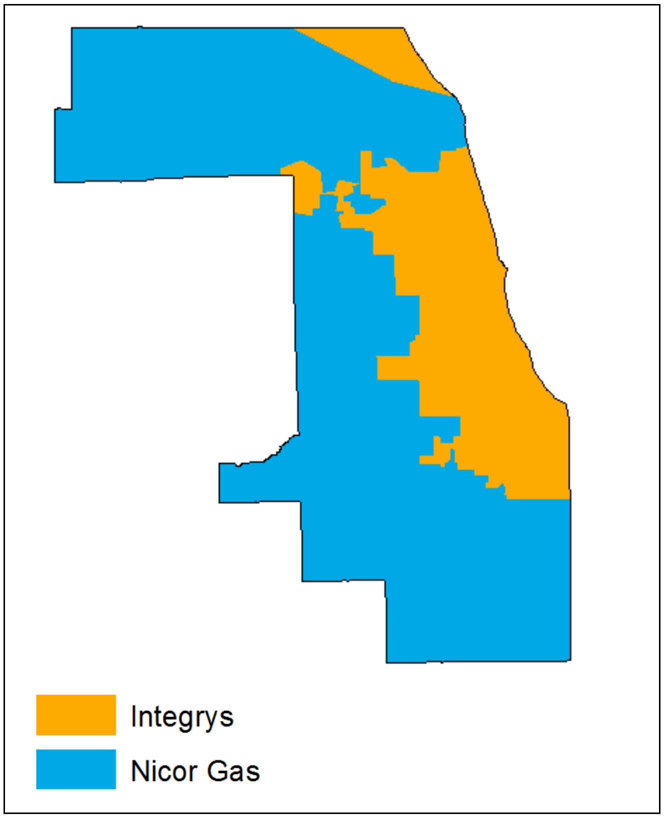


Figure 1. Natural gas utility service territories, Cook County, Illinois

In addition, PARR compiled data on residential housing stock from the Cook County assessor. The research team focused on Cook County because the assessor data on the residential housing stock is comprehensive and robust. The Cook County property assessor collects 35 data points for each home, including housing characteristics that contribute to energy usage such as exterior construction, type of attic, basement, heating and cooling systems.

[4] The research team matched data for calendar year 2005 in Cook County.

Table 1 shows a snapshot of the data collected by the Cook County assessor.

Table 1. Cook County Assessor Data Snapshot

Variable	Description
PIN	13-digit unique identifier
Address	
City	Mailing city
ZIP	5-digit zip code
Township	Assessor township within Cook County
Assessor class	Class is based on age, square footage, and number of units
Number of units	Number
Square footage	Measured as finished space
Year built	
Bedrooms	Number
Bathrooms (full)	Number
Bathrooms (half)	Number
Exterior Construction	Type of exterior construction
Roof	Type of roof construction
Basement	Type of basement
Attic	Type of attic
Heating System	Type of heating system
Air Conditioning	Type of air conditioning system
Fireplace	
Garage	Number of spaces available
Garage (exterior construction)	Exterior construction of garage

3.2 Data Cleaning and Manipulation

PARR separated base load energy use from heating and cooling load energy use using a regression model based on heating and cooling degree days. The heating and cooling energy use was then weather-normalized to ensure comparisons to future energy use or other normalized models was as accurate as possible. Other normalizations, such as for occupancy, were not done because of a lack of data at the household level.

Data including housing characteristics, electric, and natural gas data compiled by address, to create a complete dataset by individual home. Because of the unique address formatting styles particular to each dataset (ex. Ave vs. Avenue), address cleaning was required.

Address cleaning was performed through a series of Perl scripts making heavy use of the language's regular expressions capabilities to identify, split, and extract complex character sequences. The output files from the cleaning process were imported into a MySQL database, and queries to that database were used to match addresses across data sources.

This left a dataset of 464,745 homes, representing 43% of the population of nearly 1.1 million homes. Outliers were removed using the following criteria.

- Homes with missing data, including energy use, square footage, year built, or number of stories. If a home was missing at least one piece of data, it was excluded from analysis.
- Homes with assessor codes 211 and 212 were deleted, to exclude:
  - 211: Two to six apartments, over 62 years
  - Mixed commercial/residential building, six units or less, less than 20,000 sq. ft.
- Homes not meeting criteria for minimum energy usage were excluded:
  - Less than 100 therms
  - Less than 100 kWh
  - An energy use intensity (kBtu/sqft/year) less than 30.
- The top 1% of homes in the energy use categories were excluded to minimize the impact of high-use outliers:
  - More than 3,246 therms annually
  - More than 28,244 kWh annually
  - An energy use intensity (kBtu/sqft/year) more than 285.

After eliminating missing data and outliers, 432,605 homes were included in analysis.

A summary of the characteristics of the general population is presented in Table 2, below.

Figure 2 shows the distribution of housing by size.

Figure 3 shows the distribution by year of construction.

Table 3 provides energy statistics.

Table 2. Characteristics of General Housing Population

Variable	Mean	Std Dev	Median	Quartile Range
Square footage	1426.8	588.0	1248.0	570.0
Year built	1951.4	25.3	1956.0	36.0
Number of bedrooms	3.1	0.8	3.0	0.0
Number of full bathrooms	1.3	0.5	1.0	1.0
Number of half bathrooms	0.4	0.5	0.0	1.0

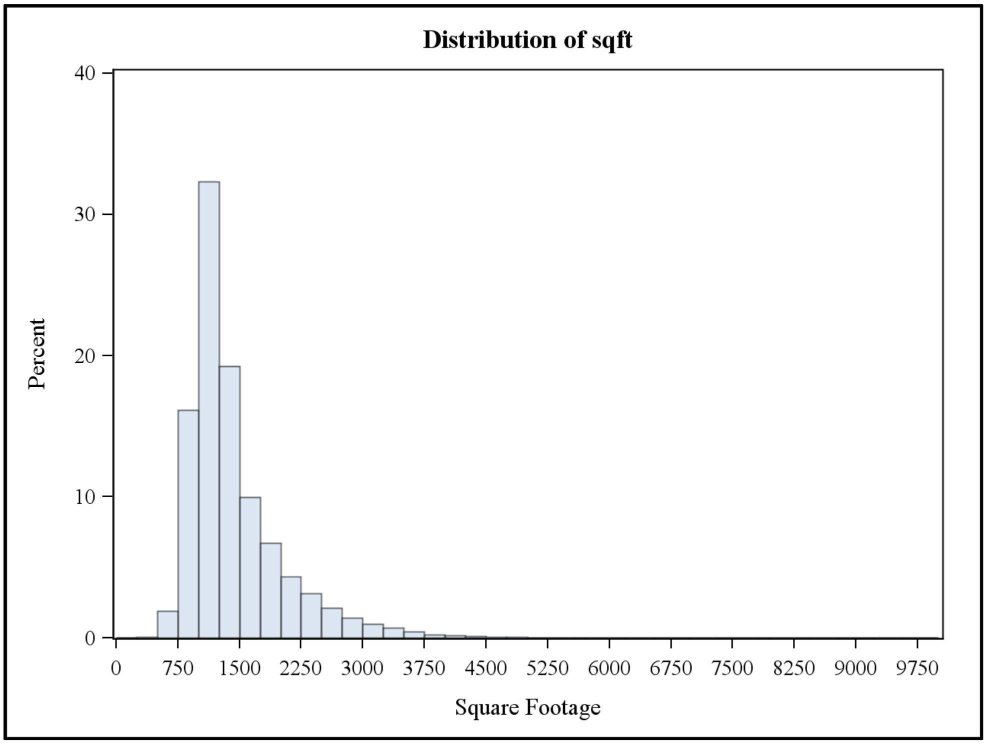


Figure 2. Distribution by floor area

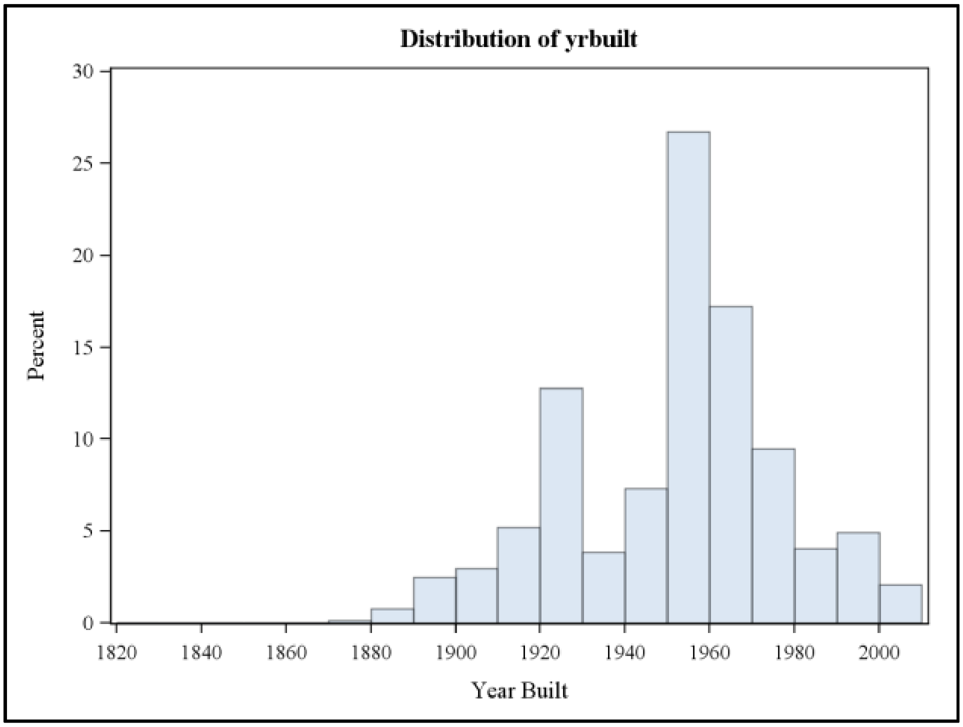


Figure 3. Distribution by year built

Table 3. Energy Statistics (presented in site energy use)

Variable	Mean	Std Dev	Median	Quartile Range
Energy Use Intensity (kBtu/sqft/yr)	130	44	125	58
kBtu	171,465	52,077	164,589	64,883
Therms	1,392	446	1,329	553
kWh	9,466	4,508	8,697	5,602
Baseload (therms)	307	125	287	143
Heating load (therms)	1,085	368	1,027	446
Baseload (kWh)	8,523	4,255	7,742	5,177
Cooling load (kWh)	943	884	722	1,039

Table 4 provides statistics on number of stories. The assessor categorizes stories as the number of floors above ground level with finished space. This includes 1-, 1.5-, and 2-story classifications. For example, the vernacular Chicago Bungalow, built with an unfinished attic on the second floor with a pitched roof and knee walls, is classified as a 1-story building in the assessor data.

Table 4. Number of Stories

Stories	Frequency	Percent
1	296,170	68.46
1.5	44,087	10.19
2	92,348	21.35

Table 5, Table 6, and Table 7 provide statistics on garage types, attic types and basement types.

Table 5. Statistics on Garage Type

Garage Type	Frequency	Percent
1 car attached	23470	5.45
1 car detached	47870	11.11
1.5 car attached	4696	1.09
1.5 car detached	26311	6.10
2 car attached	72190	16.75
2 car detached	170242	39.50
2.5 car attached	4047	0.94
2.5 car detached	14220	3.30
3 car attached	5671	1.32
3 car detached	1814	0.42
3.5 car attached	405	0.09
3.5 car detached	224	0.05
4 car attached	195	0.05
4 car detached	177	0.04
None	59479	13.80

Table 6. Statistics on Attic Type

Attic Type	Frequency	Percent
Full and Living Area	41,759	9.7%
Full and Unfinished	52,069	12.1%
None	274,063	63.6%
Partial and Living Area	14,309	3.3%
Partial and Unfinished	48,797	11.3%

Table 7. Statistics on Basement Type

Basement Type	Frequency	Percent
Crawl	20,459	4.8
Full and Rec Room	72,547	16.8
Full and Unfinished	194,065	45.0
Partial and Rec Room	57,896	13.4
Partial and Unfinished	31,942	7.4
Slab	54,102	12.5

3.3 Development of Housing Groups

The test plan outlined three segmentation methodologies to create the housing groups: statistical clustering, construction characteristics, and heating characteristics. After evaluating output results using the three methodologies, PARR decided on segmentation by construction characteristics to define the 15 housing groups.

The project's initial goal was to cluster the homes into different architectural subtypes, so that the subtypes most fit for retrofitting would be identified. Statistical cluster analysis has several different methods for choosing seeds, the starting points for the cluster groups. Because of the large size of the dataset, k-means clustering was called for. K-means clustering initially randomly generates a cluster center and selects clusters for the data points based on lowest Euclidian distance. Once all data points are assigned, the cluster averages are used for the new centers in another round of clustering based on Euclidean distance. After the re-clustering and re-centering process has been repeated enough times to meet the convergence criterion, the process is finished. Unfortunately, the data did not cluster into the different architectural subtypes as was hoped. This is largely due to the overlap of home attributes such as size, age, and frame type among different architectural styles. In the end, the clustering was based on the differences in energy use amongst the homes, which, while informative, did not group homes based on structural characteristics that would enable certain types of retrofits.

The final segmentation of housing groups is based on a three tiered system of characteristics, which are chosen based on previous program knowledge and identified contributions to energy use.

Tier 1) Construction type – either brick or not brick (includes frame and "frame and brick" houses). Table 8 provides statistics on energy use by construction type.

Table 8. Statistics on Energy Use by Construction Type

Construction Type	N Obs	Variable (measure in site energy use)	Mean	Std Dev.	Median	Quartile Range
Brick	232306	Energy Use Intensity (kBtu/sqft/year) Therms kWh	125.5 1362.7 9750.7	45.6 439.7 4553.1	118.5 1302.0 8996.0	59.0 547.0 5706.0
Frame	200299	Energy Use Intensity (kBtu/sqft/year) Therms kWh	135.6 1425.3 9136.2	42.2 451.3 4431.4	131.3 1358.0 8357.0	54.2 558.0 5442.0

Tier 2) Year built: based on three categories:

Pre-1942 (the bottom of the bimodal histogram)

1942-1978 (1978 is the year that building codes changed to include insulation)

Post-1978.

Table 9 provides statistics on energy use by year built.

Table 9. Statistics on Energy Use by Year Built

Year built	N Obs	Variable (measure in site energy use)	Mean	Std Dev	Median	Quartile Range
Pre-1942	128751	Energy Use Intensity (kBtu/sqft/year) Therms kWh	150.0 1593.0 9500.6	47.6 487.3 4729.8	144.7 1541.0 8717.0	66.6 627.0 6006.0
1942-1978	251544	Energy Use Intensity (kBtu/sqft/year) Therms kWh	129.3 1302.8 9100.5	38.2 390.3 4205.1	124.9 1253.0 8399.0	48.5 479.0 5218.0
Post-1978	52310	Energy Use Intensity (kBtu/sqft/year) Therms kWh	85.8 1323.2 11140.1	27.3 432.6 4949.5	80.6 1266.0 10252.0	33.4 520.0 6265.0

Tier 3) Number of stories:

1

1.5

2.

Number of stories was used to segment groups by size of home. The dataset in Table 10 provided for the BEopt modeling included median square footage and median therms and kWh for each of the 15 housing groups. The number of stories informs BEopt modeling in terms of volume and layout of the home, rather than square footage which implies size but not the spatial distribution of that size.

Table 10. Statistics on Energy Use by Number of Stories

Stories	N Obs	Variable (measure in site energy use)	Mean	Std Dev	Median	Quartile Range
1	296170	Energy Use Intensity (kBtu/sqft/year) Therms kWh	139.0 1330.0 8794.6	45.2 419.8 4155.6	133.8 1276.0 8117.0	59.5 528.0 5192.0
1.5	44087	Energy Use Intensity (kBtu/sqft/year) Therms kWh	128.9 1345.9 9658.0	33.6 358.9 3888.1	124.8 1298.0 9085.0	41.2 446.0 4802.0
2	92348	Energy Use Intensity (kBtu/sqft/year) Therms kWh	102.4 1611.2 11528.6	33.2 494.6 5183.2	97.8 1535.0 10717.0	44.3 635.0 6781.5

The 15 groups were assembled by using these three tiers and overlaying houses with similar energy use and structural characteristics. A short summary of each group with example photos follows. See Appendix I for more detailed information on characteristics of each housing group.

Group 1: Brick, 1978-Present, 1 to 1.5 stories (no split level)
2.5% of population
Mean Site EUI: 81.8
Mean therms: 1077
Mean kWh: 8887
Mean finished square footage: 1741



Group 2: Brick, 1978-Present, Split level (1.5 stories)
1.9% of population
Mean Site EUI: 112.6
Mean therms: 1205
Mean kWh: 10076
Mean finished square footage: 1404

Group 3: Brick, 1978-Present, 2 stories
4.7% of population
Mean Site EUI: 76.7
Mean therms: 1446
Mean kWh: 12482
Mean finished square footage: 2506


Group 4: Brick, 1942-1978, 1 to 1.5 stories (no split level)
17.9% of population
Mean Site EUI: 129.6
Mean therms: 1212
Mean kWh: 8859
Mean finished square footage: 1217



Group 5: Brick, Pre-1978, Split level (1.5 stories)
6.1% of population
Mean Site EUI: 131.5
Mean therms: 1344
Mean kWh: 9643
Mean finished square footage: 1299


Group 6: Brick, 1942-1978, 2 stories
4.8% of population
Mean Site EUI: 99.8
Mean therms: 1553
Mean kWh: 11714
Mean finished square footage: 2059


Group 7: Brick, Pre-1942, 1 to 1.5 stories (no split level)
11.6% of population
Mean Site EUI: 161.3
Mean therms: 1442
Mean kWh: 8927
Mean finished square footage: 1141


Group 8: Brick, Pre-1942, 2 stories
4.1% of population
Mean Site EUI: 117.3
Mean therms: 1757
Mean kWh: 11062
Mean finished square footage: 1884




Group 9: Frame, 1978-Present, 1 to 1.5 stories (no split level)
1.7% of population
Mean Site EUI: 91.8
Mean therms: 1217
Mean kWh: 9719
Mean finished square footage: 1801


Group 10: Frame, All years, Split level (1.5 stories)
2.1% of population
Mean Site EUI: 136.6
Mean therms: 1480
Mean kWh: 9321
Mean finished square footage: 1349


Group 11: Frame, 1978-Present, 2 stories
1.1% of population
Mean Site EUI: 73.8
Mean therms: 1749
Mean kWh: 14914
Mean finished square footage: 3178


Group 12: Frame, 1942-1978, 1 to 1.5 stories (no split level)
23.6% of population
Mean Site EUI: 135.3
Mean therms: 1268
Mean kWh: 8483
Mean finished square footage: 1185


Group 13: Frame, 1942-1978, 2 stories
3.8% of population
Mean Site EUI: 119.2
Mean therms: 1467
Mean kWh: 9802
Mean finished square footage: 1586


Group 14: Frame, Pre-1942, 1 to 1.5 stories
11.2% of population
Mean Site EUI: 158.9
Mean therms: 1608
Mean kWh: 9050
Mean finished square footage: 1254



Group 15: Frame, Pre-1942, 2 stories
2.9% of population
Mean Site EUI: 158.9
Mean therms: 1608
Mean kWh: 9050
Mean finished square footage: 2058


3.4 BEopt Modeling

The fifteen housing types (groups) identified through the data collection and analyses were then modeled using BEopt under three scenarios:

- **As-built**, to establish a common baseline for all groups based on year of construction, and to identify the non-upgrade characteristics of the group. This scenario was developed to document the building construction before adding expected upgrades that bring the building in line with the measured EUI data. It was useful to establish a common construction practice between housing groups by year of construction.
- **Today**, to apply typical upgrades in insulation, infiltration and HVAC systems in order to match the EUI energy data provided for each group.
- **Upgrade**, to use the optimization routines in BEopt and determine the potential energy savings through upgrade.

The PARR BEopt analyst relied on many industry experts to develop the assumptions in each of the three scenarios: an expert group consisting of PARR team members with background in weatherization training, insulation products, HVAC, and field retrofit practices; a local insulation contractor; and members of the NREL BEopt team.

Appendix II contains the assumptions made in each of the scenarios. A discussion regarding these modeling assumptions is provided in Sections 3.4.1 through 3.4.3, below.

3.4.1 All Cases

In all cases, PARR used the property assessor and energy data from CNT Energy to model the buildings. Number of stories, type of foundation, finished or unfinished spaces, and square footage were followed. The type of garage, number of bedrooms and baths, and type of foundation were also followed for each vintage of house. General assumptions for all vintages and scenarios are provided in the list below and specific assumptions are provided in the sections that follow.

- Assumptions on the lot size and distance to neighbors were based on homeowner input from the PARR research team and information on the size of a standard city and suburban lot.
- In all cases, the heating setpoint was set at 70 and cooling setpoint was set at 72 and left unchanged.
- Windows were modeled as double-clear (window plus storm window) in all cases and left unchanged.
- Mechanical ventilation was modeled as none for pre-1942 and spot for other years.
- Average current appliances were chosen for the models as they were only significant in evaluating the energy use in the Today scenario.
- MEL's were set at 1 for both gas (MGL) and electric.

3.4.2 As-Built Case Assumptions

Pre-1942 construction assumptions were as follows:

- Brick walls pre-1942 are double brick construction. The layers from outside to inside are: 4 inch brick, 1 inch airspace (the weep space, largely mortar and bricks connecting the inside and outside layer), an inside brick layer, wood lath with no insulation in the spaces, and 5/8 inch drywall simulating plaster. A new Concrete Masonry Unit (CMU) case was developed for the weep space plus 4 inch interior brick.
- Wood frame walls pre-1942 were modeled from the outside to inside as siding, sheathing, 2x4 uninsulated walls, and 5/8 inch drywall simulating plaster on the interior wall.
- Roofs and ceilings in both types of houses were modeled as uninsulated. Bungalows were modeled with finished attic space in the upper half story. Interzonal knee walls were modeled with no insulation and the roof above the living space was also modeled with no insulation in the As-built scenario.
- Basements were uninsulated. Crawl spaces and slabs are not common in Chicago construction.
- Infiltration assumptions were as shown: very leaky for 1 story and leaky for 2 stories. These assumptions were made based on the opinion of an expert panel without validation from field data other than the close match of the Today case with field energy use intensity. The Today scenario results supported increasing the level of house tightness for all 2-story houses in all vintages. BEopt calculates infiltration in terms of ratio of the effective leakage area of the living space to the floor area of the space for the living space, basement, and garage area. The ratios for very leaky, leaky, typical, tight, tighter, and tightest (respectively) are: 0.0009, 0.0007, 0.0005, 0.00036, 0.00018, and 0.0009.
- No clothes dryer was included—line drying is the assumption.
- Boilers were the most common for pre-1942 construction and 65% efficiency was assumed (LBNL study).
- No cooling was included in the As-built case.
- Pre-1942 gas water heating was assumed with an energy factor (EF) of 0.48 (Kelso).

1942-1978 construction assumptions were as follows:

- For brick walls, 1 inch of R3 fiberglass was added between the furring strips.
- For wood frame and interzonal walls, an R7 fiberglass batt was the typical insulation for that era.
- Ceiling and interzonal floor insulation was R11.
- Infiltration for 1 story was upgraded to leaky and 2 stories to typical.
- Furnaces replaced boilers in the average house in this time frame; an AFUE of 70% was assumed.
- In the As-built case, cooling was not assumed for this vintage.
- The gas water heater was assumed to have the same 0.48 EF as pre-1942.

Post-1978 construction assumptions were as follows:

- Brick walls became brick veneer—face brick on the outside of the house, followed by wood sheathing and a 2x4 stud wall with R11 insulation. The interior wall was assumed to be ½ inch drywall.
- Wood frame walls were assumed to be the same as brick with the brick veneer replaced by white wood siding.
- Ceiling insulation was increased to R30 based on average IECC values.
- Interzonal floor insulation was increased to R19.
- Interzonal wall insulation matched the exterior wall insulation at R 11.
- Cooling with an SEER of 10 was assumed.
- Infiltration for single story houses was set at typical and for 2-story houses was set at tight to match the results from BEopt Today measured data.

3.4.3 Today Case Assumptions

Each house was modified in BEopt with reasonable assumptions to reflect common energy upgrades likely made to houses over time. For example, the uninsulated pre-1942 groups had R7 insulation added to unconditioned attics to reflect an average practice, keeping in mind that many of these buildings are still operating with no insulation in the attics and many have a much higher insulation level. In every case, the MEL level was increased to 1.5 to match electric energy consumption and the water heater EF was increased to 0.54. Another option is to provide a series of models to bracket the range of energy performance characteristics of each group, but that option was rejected in favor of a single representative building. When the project moves to the field in a later task, each building will require baseline modeling to assess improvement to EUI. In addition to the assumptions above, the following assumptions were made for each vintage of building:

Pre-1942 construction upgrade assumptions were as follows:

- Attic insulation increased to R7.
- A gas dryer was added (not line drying).
- Cooling was added—SEER of 10 representing window air conditioners.
- Boiler efficiency was increased to 80%, representing a 1980's boiler.

1942-1978 construction upgrade assumptions were as follows:

- The attic insulation increased to R19.

- Furnace efficiency was increased to 78% AFUE, the original NAECA minimum.
- Central cooling was added with an SEER of 10.

Post-1978 construction upgrade assumptions were as follows:

Furnace was upgraded to 80% AFUE to reflect some homes upgrading to high-efficiency furnaces.

In addition to these changes, several special cases were identified to improve the accuracy of the Today model for certain groups:

- Group 1 – The median year of construction for Group 1 is 1990, 1-inch foam sheathing was added to the walls, the ceiling insulation was increased to R38, and infiltration was increased from typical to tight in both the As-built and Today cases.
- Group 4 – The majority of these houses had slab floors and that model was used only here. A later vintage bungalow, a floored attic was assumed with R19 roof insulation both in the As-built and Today cases.
- Group 7 – This group is a Pre-1942 bungalow style with an upper half story in the attic. A floored attic was assumed for As-built. That assumption was not changed for the Today case because floored attics are typically not insulated beneath the floor. In this case, there were very short interzonal walls that are inaccessible and therefore uninsulated.
- Group 11 – This is the largest category of homes representing the lakeshore mansions. Electricity consumption was beyond that predicted at an MEL of 1.5. The MEL was increased to 2.0 presumably for the increased number of electronic devices.
- Group 14 – This is the only group with a full unfinished attic. A floored attic was modeled for the As-built case, typical for bungalows. For the Today case, R3 roof insulation was added to reflect an average insulation value that would be added if the attic were partially finished.

4 Results

The result of the BEopt modeling effort was that every group had a source EUI within 10% of the measured value provided by CNT Energy—the PARR team's goal. It must be emphasized that some of the modeling assumptions were made with the 10% agreement goal in mind, but based on reasonable insights into the group construction detail. Figure 4 shows the EUI values across the As-built, Today, CNT Energy data, and the Upgrade cases. This figure shows good agreement between modeling results and CNT Energy data, the difference between the As-built assumption and the Today assumption, and the potential for energy savings in the Upgrade case. Figure 5 shows similar comparisons for gas energy use, in therms. Gas energy use reduction drives the source EUI reduction in this cold climate.

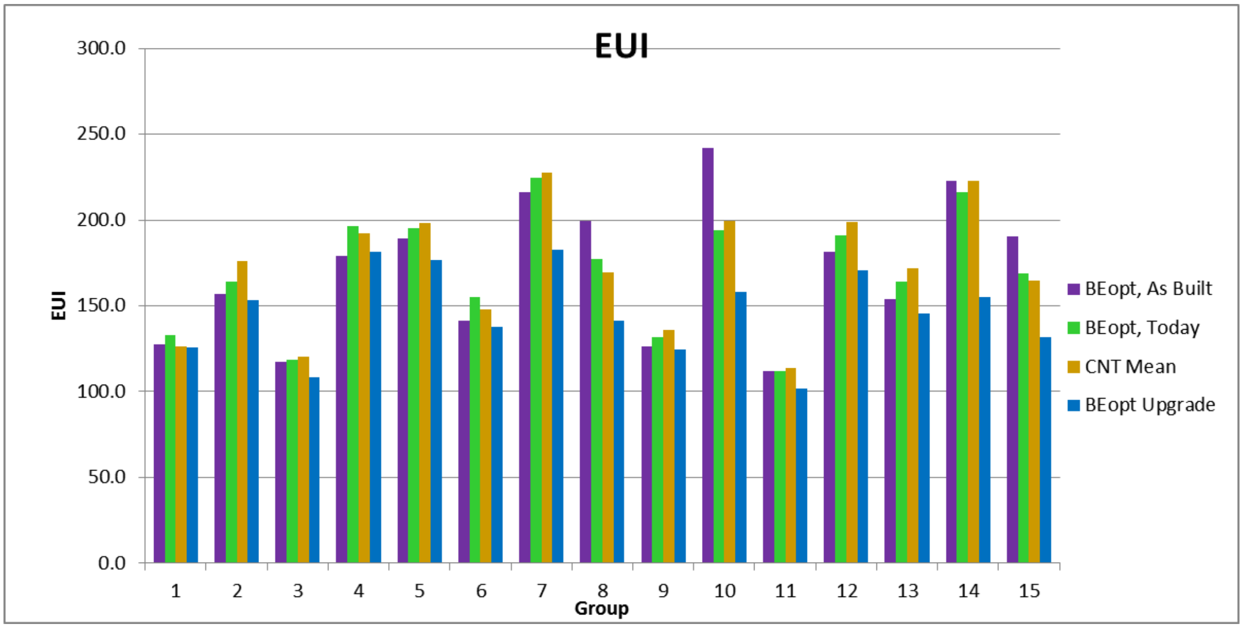


Figure 4. Source EUI from all scenarios - As-built, Today, CNT, BEopt Upgrade

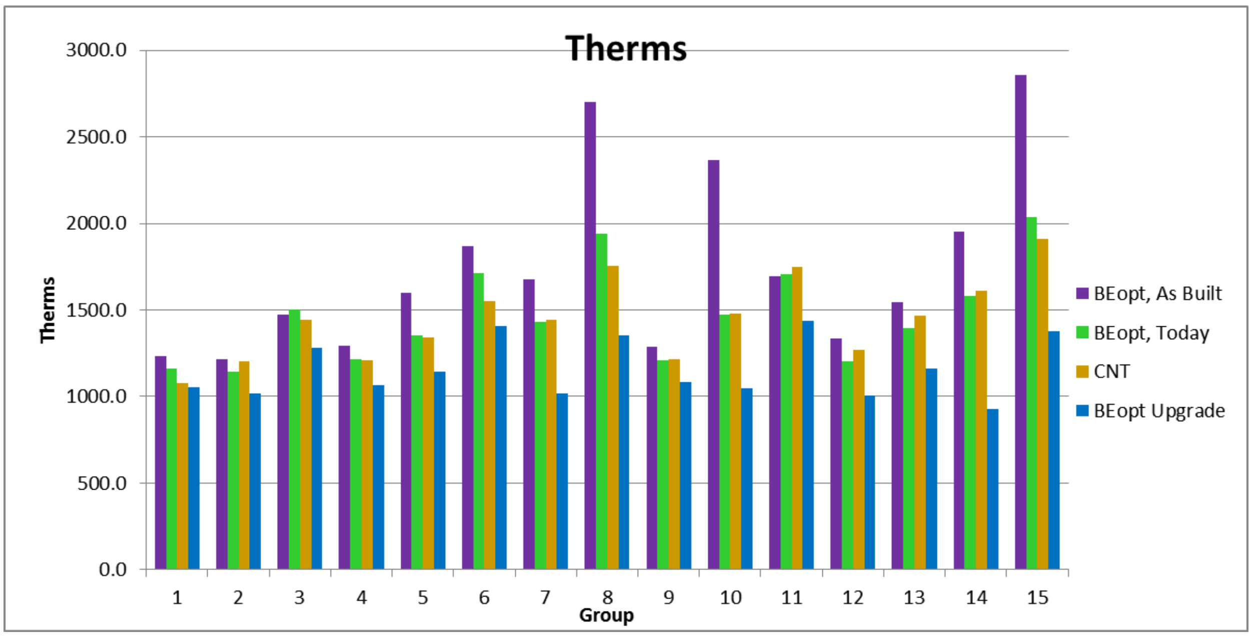


Figure 5 Therms from all scenarios - As-built, Today, CNT, BEopt Upgrade

Table 11, below, shows the percent difference between the modeled and CNT utility data on Source EUI, Therms, and kWh. With this agreement, the project moved on to selection of the top three candidates for field implementation.

Table 11. BEopt Today Case Model Results by Group Compared to CNT Data

	Source EUI, Btu/sq. ft.			Gas in Therms			Electricity in kWh		
GROUP	BEopt, Today	CNT Mean	Dev, %	BEopt, Today	CNT Mean	Dev, %	BEopt, Today	CNT Mean	Dev, %
1	132.7	126.2	5%	1161.5	1077.0	8%	9074.7	8887	2%
2	164.1	176.1	-7%	1146.5	1205.0	-5%	9159.2	10076	-9%
3	118.7	120.2	-1%	1502.9	1446.0	4%	11607.5	12482	-7%
4	196.4	192.3	2%	1215.7	1212.0	0%	9254.1	8859	4%
5	195.1	198.2	-2%	1350.6	1344.0	0%	9227.1	9643	-4%
6	155.2	147.7	5%	1712.9	1553.0	10%	11533.5	11714	-2%
7	224.7	227.8	-1%	1430.6	1442.0	-1%	8724.6	8927	-2%
8	177.1	169.3	5%	1940.9	1757.0	10%	10607.6	11062	-4%
9	132.0	135.7	-3%	1209.5	1217.0	-1%	9203.6	9719	-5%
10	193.9	199.1	-3%	1473.6	1480.0	0%	8771.6	9321	-6%
11	111.8	114.0	-2%	1706.0	1749.0	-2%	14733.4	14914	-1%
12	191.0	199.0	-4%	1204.6	1268.0	-5%	8256.8	8483	-3%
13	163.9	172.0	-5%	1395.6	1467.0	-5%	9367.3	9802	-4%
14	216.4	222.9	-3%	1578.7	1608.0	-2%	8624.4	9050	-5%
15	168.6	164.8	2%	2034.9	1913.0	6%	10869.8	11348	-4%

4.1 Selection Criteria

PARR identified three important criteria to use in identifying the top three housing groups to target for retrofit. They are:

- Largest potential for cost-effective retrofit
- Highest energy use intensity
- Frequency of the housing type.

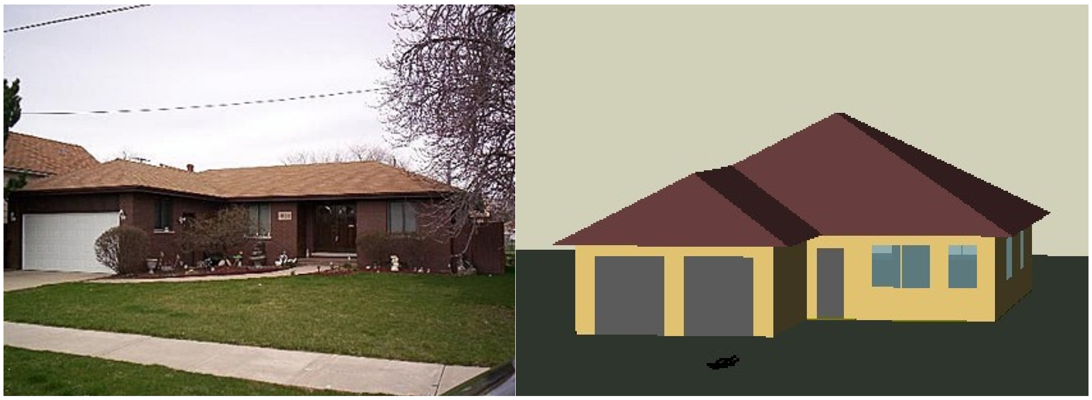
The first criteria are met through the creation of BEopt retrofit packages. BEopt was given a standard list of potential retrofit measures for infiltration, ceiling or roof insulation, space heating efficiency, space cooling efficiency, and water heater efficiency. Wall insulation and window upgrades were considered but were not selected for any case due to the high cost of the measure. Space cooling efficiency upgrade was modeled for several cases but was not selected by BEopt, presumably because of the short cooling season in Chicago.

The second and third criteria are satisfied through calculating energy savings as a percentage of source EUI and using the number of houses in the calculation of total energy savings.

4.2 Model Results

A description of each house and the upgrades proposed from the BEopt modeling is provided in the remainder of this section.

Group 1: Brick, 1978-Present, 1 to 1.5 stories (no split level)
Mean finished square footage: 1741



BEopt Results:

Category	Today	Upgrade
Infiltration	Tight	No change
Unfinished Attic	Ceiling R38 Fiberglass Batts, Vented	Ceiling R49 Fiberglass Blown-In, Vented
Furnace/Boiler	Gas, AFUE 80% Furnace	No change
Water Heater	Gas .54 EF	No change

Discussion:
For this group, BEopt chose increasing insulation levels in the attic as the only cost-effective upgrade, likely because this group represents the newest construction with low infiltration and good equipment efficiency.

Group 2: Brick, 1978-Present, Split level (1.5 stories)
Mean finished square footage: 1404

BEopt Results:

Category	Today	Upgrade
Infiltration	Typical	Tight
Unfinished Attic	Ceiling R30 Fiberglass Batts, Vented	Ceiling R38 Fiberglass Blown-In, Vented
Furnace/Boiler	Gas, AFUE 80% Furnace	No change
Water Heater	Gas .54 EF	Gas Premium (0.67 EF)

Discussion:
For this group, BEopt chose upgrading infiltration levels to tight (Group 2 was modeled as tight) because houses above 1 story best matched their EUI when modeled as typical. Increasing attic insulation levels slightly was cost effective (adding R8 to the existing batts) to a baseline of R38 (as in Group 1) was also cost effective. Increasing water heater EF may have been chosen because of the low cost of the insulation upgrade.

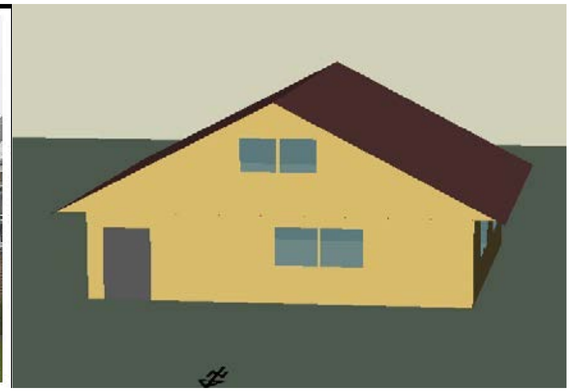
Group 3: Brick, 1978-Present, 2 stories
Mean finished square footage: 2506

BEopt Results:

Category	Today	Upgrade
Infiltration	Typical	Tight
Unfinished Attic	Ceiling R38 Fiberglass Batts, Vented	No change
Furnace/Boiler	Gas, AFUE 80% Furnace	No change
Water Heater	Gas .54 EF	Gas Premium (0.67 EF)

Discussion:
For this group, BEopt chose upgrading infiltration levels to tight (Group 3 was modeled as tight) because houses above 1 story best matched their EUI when modeled as typical. Increasing attic insulation levels slightly was not cost effective likely because the R38 baseline was modeled. Increasing the water heater EF may have been chosen because of the low cost of the infiltration upgrade.

Group 4: Brick, 1942-1978, 1 to 1.5 stories (no split level)
Mean finished square footage: 1217

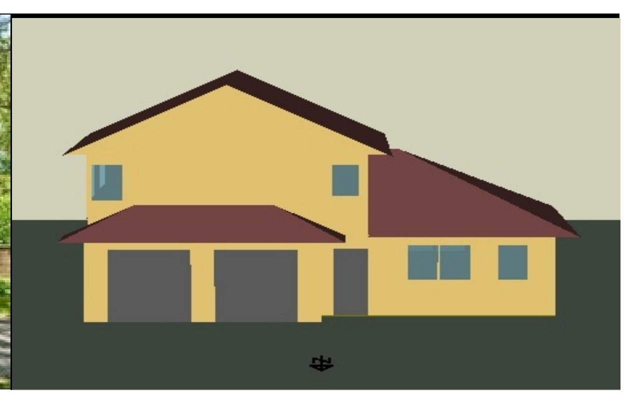



BEopt Results:

Category	Today	Upgrade
Infiltration	Leaky	Typical
Unfinished Attic	Ceiling R19 Fiberglass Blown-In, Vented Roof R19 Fiberglass	No change
Furnace/Boiler	Gas, AFUE 78% Furnace	No change
Water Heater	Gas .54 EF	Gas Premium (0.67 EF)

Discussion:
For this 1942–1978 group, BEopt chose upgrading infiltration levels one step to typical because a two-step upgrade was not considered realistic for this vintage and was not modeled. Bungalow attic insulation was modeled as part ceiling (where the attic was not covered by the finished attic space) and part roof. The roof insulation level was constrained by the roof construction but BEopt did not choose to increase ceiling insulation, likely because of the marginal returns for the small area. Further modeling will be done in this area. Increasing the water heater EF may have been chosen because of the low cost of the infiltration upgrade.

Group 5: Brick, Pre-1978, Split level (1.5 stories)
Mean finished square footage: 1299

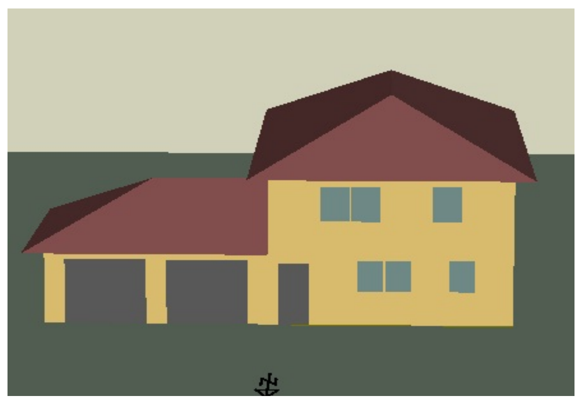



BEopt Results:

Category	Today	Upgrade
Infiltration	Leaky	Typical
Unfinished Attic	Ceiling R19 Fiberglass Blown-In, Vented	Ceiling R38 Fiberglass Blown-In, Vented
Furnace/Boiler	Gas, AFUE 78% Furnace	Gas, AFUE 92.5% Furnace
Water Heater	Gas .54 EF	No change

Discussion:
For this pre-1978 group, BEopt chose upgrading infiltration levels one step to typical because a two-step upgrade was not considered realistic for this vintage and was not modeled. Attic insulation was brought up to the R38 level as in some of the cases above. BEopt chose to increase the furnace efficiency in this case rather than the water heater efficiency possibly due to the large thermal envelope area compared to the floor area of the house.

Group 6: Brick, 1942-1978, 2 stories
Mean finished square footage: 2059

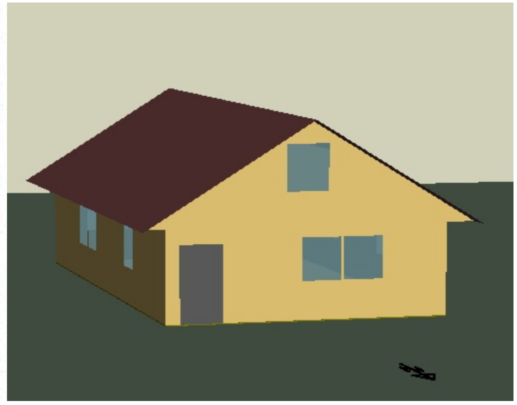



BEopt Results:

Category	Today	Upgrade
Infiltration	Typical	No change
Unfinished Attic	Ceiling R19 Fiberglass Blown-In, Vented	Ceiling R38 Fiberglass Blown-In, Vented
Furnace/Boiler	Gas, AFUE 78% Furnace	Gas, AFUE 92.5% Furnace
Water Heater	Gas .54 EF	Gas Premium (0.67 EF)

Discussion:
For this 1942-1978 2-story group, BEopt did not chose to upgrade infiltration but upgraded all other categories. Infiltration for this house best fit the EUI data when modeled as typical and BEopt did not chose to upgrade that level. Attic insulation was brought up to the R38 level as in some of the cases above. BEopt chose to increase the furnace efficiency in this case possibly due to the large thermal envelope area compared to the floor area of the house. Water heater efficiency was increased possibly because this is a larger house with more bedrooms and more occupants.

Group 7: Brick, Pre-1942, 1 to 1.5 stories (no split level)
Mean finished square footage: 1141

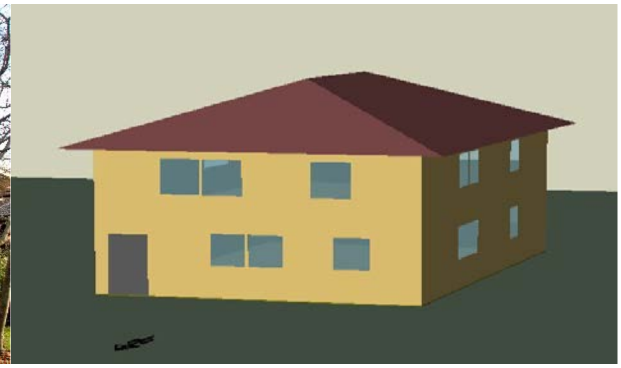


BEopt Results:

Category	Today	Upgrade
Infiltration	Very Leaky	Leaky
Unfinished Attic	Ceiling R7 Fiberglass Blown-In, Vented; R19 Fiberglass Roof Insulation	No change
Furnace/Boiler	Gas, 80% AFUE Boiler	Gas, 95% AFUE Boiler
Water Heater	Gas .54 EF	Gas Premium (0.67 EF)

Discussion:
For this pre-1942 bungalow-style house, the results were similar to the 1942-1978 bungalow above: infiltration upgraded one level, ceiling insulation unchanged due to the constraint in roof insulation and small area of ceiling insulation. In this case, all the equipment was upgraded. The boiler was likely upgraded because the walls are uninsulated and heating systems are a cost-effective upgrade. Upgrading the water heater in this small house does not seem to be cost effective; PARR will investigate that upgrade further.

Group 8: Brick, Pre-1942, 2 stories
Mean finished square footage: 1884

BEopt Results:

Category	Today	Upgrade
Infiltration	Leaky	Typical
Unfinished Attic	Ceiling R7 Fiberglass Blown-In, Vented	Ceiling R30 Fiberglass Blown-In, Vented
Furnace/Boiler	Gas, 80% AFUE Boiler	Gas, 95% AFUE Boiler
Water Heater	Gas .54 EF	Gas Premium (0.67 EF)

Discussion:
For this pre-1942 2 story, BEopt chose to upgrade all four categories. The infiltration upgraded one level because PARR believes a two-level upgrade is unreasonable and it was not modeled. The insulation was upgraded to R30 in this case instead of R38, possibly because of the poor performance of the insulation in the perimeter of the attic due to the low-slope roof. In this case, all the equipment was upgraded. The boiler was likely upgraded because the walls are uninsulated and heating systems are a cost-effective upgrade. Upgrading the water heater in this mid-size house may be cost effective due to the number of bedrooms.

Group 9: Frame, 1978-Present, 1 to 1.5 stories (no split level)
Mean finished square footage: 1801


BEopt Results:

Category	Today	Upgrade
Infiltration	Typical	No change
Unfinished Attic	Ceiling R38 Fiberglass Batts, Vented	No change
Furnace/Boiler	Gas, AFUE 78% Furnace	Gas, AFUE 92.5% Furnace
Water Heater	Gas .54 EF	No change

Discussion:
For this post-1978 house, BEopt chose to upgrade only the furnace. The typical infiltration level may be suitable for this house. The ceiling insulation level at R38 is a common optimum level as in the other groups. Increasing the furnace efficiency may be cost effective because of the higher cost of insulating the large attic. The water heater was not upgraded in this case likely because of the cost of increasing the furnace in this recent vintage house.

Group 10: Frame, All years, Split level (1.5 stories)
Mean finished square footage: 1349


BEopt Results: (note – BEopt does not draw split level houses for drawing at right)

Category	Today	Upgrade
Infiltration	Very Leaky	Leaky
Unfinished Attic	Ceiling R7 Fiberglass Blown-In, Vented Roof R19 Fiberglass	Ceiling R38 Fiberglass Blown-In, Vented Roof R19 Fiberglass
Furnace/Boiler	Gas, 80% AFUE Boiler	Gas, 95% AFUE Boiler
Water Heater	Gas .54 EF	Gas Premium (0.67 EF)

Discussion:
Group 10 was modeled as a 1942 frame bungalow-style house because it best fit the EUI numbers from the field. Only the back half was modeled as a 1.5 story to match the split level description (note BEopt does not draw split-level houses). The results were similar to the 1942 Group 7 bungalow above, except the insulation level was increased: The infiltration upgraded one level as constrained by the modelers and the ceiling insulation was upgraded, likely due to the large ceiling area in the front of the house that had only R7 insulation on it. Again, in this

case, all the equipment was upgraded. The boiler was likely upgraded because the walls are uninsulated and heating systems are a cost-effective upgrade. Upgrading the water heater in this small house does not seem to be cost effective; PARR will investigate that upgrade further.

Group 11: Frame, 1978-Present, 2 stories
Mean finished square footage: 3178


BEopt Results:

Category	Today	Upgrade
Infiltration	Typical	Tight
Unfinished Attic	Ceiling R38 Fiberglass Batts, Vented	No change
Furnace/Boiler	Gas, AFUE 80% Furnace	No change
Water Heater	Gas .54 EF	Gas Premium (0.67 EF)

Discussion:
Identical to Group 3, BEopt chose upgrading infiltration levels to tight because houses above 1 story best matched their EUI when modeled as typical and only a 1-level increase was permitted. Increasing attic insulation levels slightly was not cost effective likely because the R38 baseline was modeled. Increasing the furnace efficiency was not cost effective due to the good insulation level in the thermal envelope. Increasing the water heater EF may have been chosen because of the low cost of the infiltration upgrade.

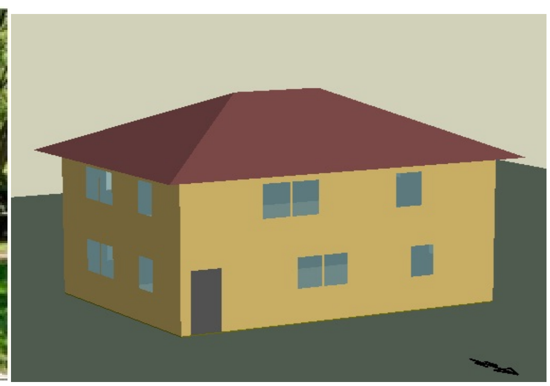
Group 12: Frame, 1942-1978, 1 to 1.5 stories (no split level)
Mean finished square footage: 1185


BEopt Results:

Category	Today	Upgrade
Infiltration	Leaky	Typical
Unfinished Attic	Ceiling R19 Fiberglass Blown-In, Vented	Ceiling R49 Fiberglass Blown-In, Vented
Furnace/Boiler	Gas, AFUE 78% Furnace	No change
Water Heater	Gas .54 EF	No change

Discussion:
This 1942–1978 group was modeled as a single story to best match the EUI, unlike group 4. BEopt chose upgrading infiltration levels one step to typical because a two-step upgrade was not considered realistic for this vintage and was not modeled. BEopt chose a higher level of attic insulation due to the large flat ceiling area and partially insulated walls. The furnace was not upgraded in this case likely due to the lower load for this smaller house with good attic insulation. The water heater was likely not upgraded due to the lower occupancy numbers with fewer bedrooms.

Group 13: Frame, 1942-1978, 2 stories
Mean finished square footage: 1586

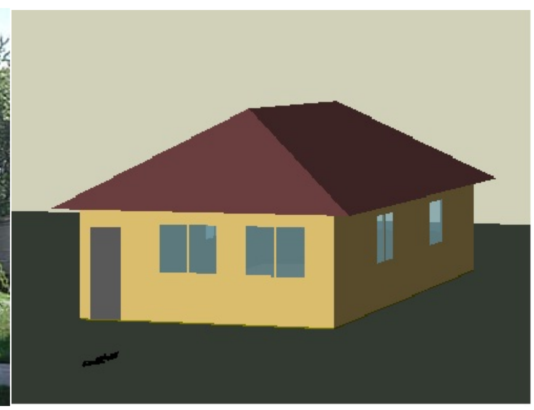



BEopt Results:

Category	Today	Upgrade
Infiltration	Leaky	Typical
Unfinished Attic	Ceiling R11 Fiberglass Blown-In, Vented	Ceiling R38 Fiberglass Blown-In, Vented
Furnace/Boiler	Gas, AFUE 78% Furnace	Gas, AFUE 92.5% Furnace
Water Heater	Gas .54 EF	No change

Discussion:
For this 1942-1978 2-story group, and unlike Group 6, BEopt upgraded all categories except the water heater. Infiltration was upgraded to typical as in most cases. Attic insulation was brought up to the R38 level as in many of the cases above. BEopt chose to increase the furnace efficiency in this case possibly due to the large thermal envelope area compared to the floor area of the house. The water heater was not upgraded in this case.

Group 14: Frame, Pre-1942, 1 to 1.5 stories
Mean finished square footage: 1254

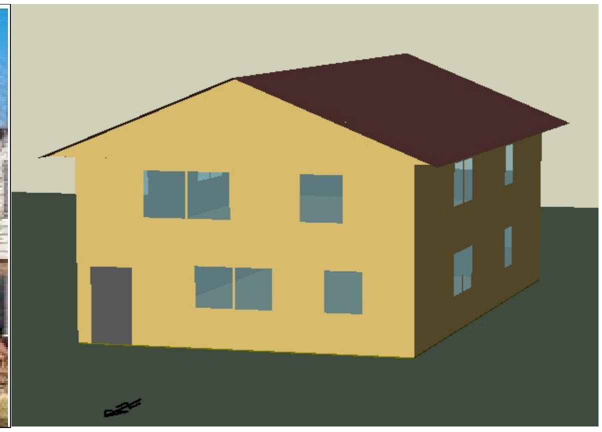



BEopt Results:

Category	Today	Upgrade
Infiltration	Very Leaky	Leaky
Unfinished Attic	Floored R3 roof insulation unvented	Ceiling R38 Fiberglass Blown-In, Vented
Furnace/Boiler	Gas, 80% AFUE Boiler	Gas, 95% AFUE Boiler
Water Heater	Gas .54 EF	Gas Premium (0.67 EF)

Discussion:
For this pre-1942 1-story house, infiltration was upgraded one level and ceiling insulation was increased due to the large flat mostly uninsulated ceiling. In this case, all the equipment was upgraded. The boiler was likely upgraded because the walls are uninsulated and heating systems are a cost-effective upgrade. Upgrading the water heater in this small house may be cost effective because wall insulation was not considered.

Group 15: Frame, Pre-1942, 2 stories
Mean finished square footage: 2058



BEopt Results:

Category	Today	Upgrade
Infiltration	Leaky	Typical
Unfinished Attic	Ceiling R7 Fiberglass Blown-In, Vented	Ceiling R38 Fiberglass Blown-In, Vented
Furnace/Boiler	Gas, 80% AFUE Boiler	Gas, 95% AFUE Boiler
Water Heater	Gas .54 EF	Gas Premium (0.67 EF)

Discussion:
For this pre-1942 2 story, as in Group 8, BEopt chose to upgrade all four categories. The infiltration upgraded one level because PARR believes a two-level upgrade is unreasonable and it was not modeled. The insulation was upgraded to R38 in this case instead of R30, possibly because of the better performance of the insulation in the perimeter of the attic due to the hip roof design. In this case, all the equipment was upgraded. The boiler was likely upgraded because the walls are uninsulated and heating systems are a cost-effective upgrade. Upgrading the water heater in this mid-size house may be cost effective due to the number of bedrooms.

4.3 Analysis

The potential source energy reduction for each group was calculated using BEopt output reports for gas and electric site energy reduction and converting the values to source energy using multipliers for Chicago. Table 12, below, provides the percentage source energy reduction by group and then ranked to identify the highest percentage reduction. Appendix III contains detailed tables and graphs showing energy savings in therms, source EUI, and kWh.

The top Source EUI energy-savings percentage by group are groups 14, 15, and 8 representing the Pre-1942 frame bungalow, pre-1942 frame 2 story, and the pre-1942 brick 2-story houses. This analysis reflects the first two criteria needed to determine the target groups for retrofit.

Table 12. Source EUI Reduction Percentage by Group

Group	Source EUI Reduction, %[5]	Rank
14	28%	1
15	22%	2
8	20%	3
10	19%	4
7	19%	5
6	11%	6
12	11%	7
13	11%	8
11	9%	9
5	9%	10
3	9%	11
4	8%	12
2	7%	13
9	6%	14
1	5%	15

The third criteria applies the optimal energy saving to the number of homes in a group and then by size of the home to arrive at an annual savings potential in millions of Btu for each group. Table 13, below provides the final rank by group using that metric.

Table 13. Final Rank by Group

Group	Number of homes	Source EUI Savings %	Total Source Energy Savings (million Btu)	Rank
14	48365	28%	3,718,320	1
12	101957	11%	2,471,892	2
7	50239	19%	2,409,359	3
4	77435	8%	1,369,018	4
8	17629	20%	1,179,926	5
15	12479	22%	950,418	6
6	20755	11%	738,176	7
5	26445	9%	638,185	8
3	20530	9%	535,369	9
13	16411	11%	474,008	10
10	9225	19%	445,641	11
11	4544	9%	140,783	12
1	10856	5%	132,042	13

[5] For later discussion: BEopt does not identify any cost-effective retrofit packages that will lead to 30% source savings.

Group	Number of homes	Source EUI Savings %	Total Source Energy Savings (million Btu)	Rank
2	8417	7%	130,548	14
9	7318	6%	99,835	15

The result of the analysis then identifies the following groups as the top three groups in the Chicagoland area for retrofit:

1) Group 14: Frame, Pre-1942, 1 to 1.5 stories
2) Group 12: Frame, 1942-1978, 1 to 1.5 stories
3) Group 7: Brick, Pre-1942, 1 to 1.5 stories

These three groups include 46% of the housing stock in Cook County, and represent the potential for over 100 million therms of source energy savings per year[6].

5 Conclusions

In this study, PARR identified 15 groups that cluster the Cook County, Illinois, single-family detached houses by vintage, construction detail, and energy use intensity. The team further characterized each group using assessor data and utility energy billing data, and used this data to build three BEopt cases for each group: As-built, Today, and with Upgrade using the most cost-effective measures. The BEopt analysis predicts significant energy savings in three 1 to 1.5 story groups: pre-1942 brick, pre-1942 frame, and 1942-1978 brick construction. The groups save 28%, 19%, and 11% of source energy respectively, and because of the large number of these houses across the geographic area, they represent the first, second, and third largest energy saving potential by housing type. PARR identifies these three groups as those best matching the criteria set forth in this study.

Next year, PARR will take these results into the field to improve the assumptions used, validate the model, gather data on the actual upgrades between the As-built and Today cases, and develop a better retrofit cost database for these buildings. PARR also expects to explore the cost effectiveness of additional measures that could be used to achieve the 30% energy savings target for these homes, and to better define and document the costs and measured savings of single-family home retrofits. This will help: (1) increase visibility of the measures to energy efficiency portfolios of utility companies, (2) provide achievable savings predictions based on home type to single-family homeowners who are interested in cost-effective measures, and (3) create the most cost-effective retrofit package to market to those homeowners.
The following research questions were addressed in this project:

What are the most common housing types in Cook County? Fifteen groups were identified and their populations are presented in this report.

What are the energy use characteristics of these housing types? Source and site energy use for each group are provided in this report.

[6] If every home in Cook County that is a part of the top three groups were to be retrofitted.

Can large datasets be used to identify cost-effective retrofit opportunities? PARR was successful in segmenting nearly 500,000 buildings into 15 groups and identifying retrofit opportunities.

What are the types of housing to target for retrofit packages? This topic is covered in some depth in the Analysis section.

Do identified databases provide sufficient detail for modeling inputs? PARR was able to model the 15 groups to within 10% of measured EUI by making reasonable assumptions regarding construction characteristics and upgrades since construction.

What housing characteristics are most significant toward determining cost effectiveness of retrofit? Through statistical analysis and three clustering techniques, the characteristics in the CNT Energy dataset found to be most significant are the home vintage, construction type, and size.

What is the relationship between housing type energy intensity and potential cost-effective energy savings? PARR identified that the higher energy-intensive structures were the best opportunity for upgrade, but factoring in the cost to upgrade and the size of the population provided target groups that were not always the most energy intensive or the most cost effective. The outcome of this study is a methodology to customize prescriptive retrofit packages to distinct housing groups at scale.

Although the housing types presented here and the retrofit packages presented are specific to the cold climate of northern Illinois, the segmentation methodology presented in this report is intended to be replicable elsewhere. This approach can have dramatic impact on how broad-scale retrofit implementation programs are developed, implemented and brought to scale.

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Appendix I – Detail on Housing Group Characteristics

This appendix provides the detail on housing group characteristics that were used for the basis of developing the 15 groups and then carried forward into the BEopt modeling assumptions.

GROUP	Construction	Year	Stories
1	Brick	1978-Present	1 to 1.5 (no split level)
2	Brick	1978-Present	1.5 - split level
3	Brick	1978-Present	2
4	Brick	1942-1978	1 to 1.5 (no split level)
5	Brick	Pre-1978	1.5 - split level
6	Brick	1942-1978	2
7	Brick	Pre-1942	1 to 1.5 (no split level)
8	Brick	Pre-1942	2
9	Frame	1978-Present	1 to 1.5 (no split level)
10	Frame	All	1.5 - split level
11	Frame	1978-Present	2
12	Frame	1942-1978	1 to 1.5 (no split level)
13	Frame	1942-1978	2
14	Frame	Pre-1942	1 to 1.5 (no split level)
15	Frame	Pre-1942	2

			Square Footage		
GROUP	N Obs	% of Population	Mean	Std Dev	Median
1	10856	2.5%	1741	474	1720
2	8417	1.9%	1404	264	1368
3	20530	4.7%	2506	673	2425
4	77435	17.9%	1217	354	1136
5	26445	6.1%	1299	274	1256
6	20755	4.8%	2059	620	1987
7	50239	11.6%	1141	360	1072
8	17629	4.1%	1884	549	1784
9	7318	1.7%	1801	637	1641
10	9225	2.1%	1349	282	1303
11	4544	1.1%	3178	909	3146
12	101957	23.6%	1185	301	1114
13	16411	3.8%	1586	565	1427
14	48365	11.2%	1254	357	1176
15	12479	2.9%	2058	624	1962

	Year built			Site EUI		
GROUP	**Mean**	**Std Dev**	**Median**	**Mean**	**Std Dev**	**Median**
1	1991	7	1990	81.8	25	78.4
2	1987	6	1987	112.6	26.2	109.9
3	1992	7	1993	76.7	18.3	74.5
4	1959	8	1958	129.6	39.8	123.7
5	1968	6	1968	131.5	33.4	127.2
6	1962	11	1964	99.8	29.7	94.5
7	1917	14	1921	161.3	49.2	157.1
8	1911	16	1910	117.3	32.4	113.6
9	1992	8	1991	91.8	32.4	85.5
10	1966	8	1964	136.6	35.1	132.7
11	1996	6	1998	73.8	20.7	70.4
12	1958	7	1958	135.3	37.7	131.4
13	1951	7	1950	119.2	31.8	116.4
14	1924	10	1926	158.9	44.6	156.2
15	1922	14	1923	116	30.1	112.8

	Therms			kWh		
GROUP	**Mean**	**Std Dev**	**Median**	**Mean**	**Std Dev**	**Median**
1	1077	351	1033	8887	4097	8122
2	1205	276	1174	10076	3771	9547
3	1446	406	1393	12482	4914	11721
4	1212	379	1161	8859	4065	8189
5	1344	360	1298	9643	3922	9041
6	1553	435	1499	11714	5003	10960
7	1442	433	1400	8927	4382	8265
8	1757	525	1696	11062	5213	10214
9	1217	409	1171	9719	4454	8903
10	1480	372	1449	9321	3860	8733
11	1749	502	1681	14914	5678	14209
12	1268	356	1228	8483	3910	7858
13	1467	424	1406	9802	4653	8952
14	1608	445	1570	9050	4463	8337
15	1913	549	1857	11348	5374	10460

	Central Gas Furnace	Central Gas Furnace	Gas Boiler	Gas Boiler	CentralAC	CentralAC	Window AC or None	Window AC or None
GROUP	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
1	10836	99.82%	20	0.18%	9401	86.60%	1455	13.40%
2	8413	99.95%	4	0.05%	6345	75.38%	2072	24.62%
3	20514	99.92%	16	0.08%	18375	89.50%	2155	10.50%
4	73861	95.38%	3574	4.62%	27032	34.91%	50403	65.09%
5	25504	96.44%	941	3.56%	14745	55.76%	11700	44.24%
6	19794	95.37%	961	4.63%	12982	62.55%	7773	37.45%
7	39810	79.24%	10429	20.76%	5342	10.63%	44897	89.37%
8	11696	66.35%	5933	33.65%	3800	21.56%	13829	78.44%
9	7295	99.69%	23	0.31%	6078	83.06%	1240	16.94%
10	8505	92.20%	720	7.80%	5528	59.92%	3697	40.08%
11	4529	99.67%	15	0.33%	4343	95.58%	201	4.42%
12	95745	93.91%	6212	6.09%	43400	42.57%	58557	57.43%
13	15511	94.52%	900	5.48%	6989	42.59%	9422	57.41%
14	25459	52.64%	22906	47.36%	5147	10.64%	43218	89.36%
15	5993	48.02%	6486	51.98%	2867	22.97%	9612	77.03%

GROUP	**Attic Description**						
	Full and Apartment	**Full and Living Area**	**Full and Unfinished**	**None**	**Partial &Living Area**	**Partial and Unfinished**	**Total**
1	0	385	93	9679	454	222	10833
2	0	9	15	8254	16	79	8373
3	0	79	305	19015	477	581	20457
4	0	6488	5799	52727	2652	9469	77135
5	0	27	444	22625	106	3190	26392
6	0	222	767	17321	302	2080	20692
7	7	13549	8843	19160	3212	5188	49959
8	3	1117	3331	8615	832	3620	17518
9	0	132	55	6725	181	210	7303
10	0	20	150	7934	52	1039	9195
11	0	39	101	4020	141	232	4533
12	0	8585	11280	68057	2028	11641	101591
13	0	150	972	13060	126	2055	16363
14	4	10277	17722	10484	3189	6564	48240
15	0	680	2192	6387	541	2627	12427

GROUP	Basement Description								
	Crawl	Full and Apartment	Full and Rec Room	Full and Unfin-ished	Partial and Apartment	Partial and Rec Room	Partial and Unfinished	Slab	Total
1	687	0	677	3756	0	712	2229	2772	10833
2	42	0	396	22	0	7707	183	23	8373
3	628	0	1484	11021	0	817	5267	1240	20457
4	11430	1	10330	18637	0	5378	6839	24520	77135
5	46	0	734	85	0	25205	247	75	26392
6	1311	0	2105	5093	0	3175	4755	4253	20692
7	1143	8	7548	27062	1	759	2305	11133	49959
8	261	0	2315	11279	0	421	1431	1811	17518
9	159	0	1063	3587	0	309	1016	1169	7303
10	9	0	437	27	0	8620	94	8	9195
11	38	1	851	2837	0	196	501	109	4533
12	4264	3	26130	59221	0	2607	4195	5171	101591
13	188	0	4972	8567	0	979	1194	463	16363
14	206	4	10890	34490	1	635	858	1156	48240
15	47	0	2598	8381	0	374	828	199	12427

Appendix II – BEopt Modeling Assumptions Tables

As-built					
Building					
Lot size/distance to neighbor	**Size**	**Distance to Neighbor**	**Age**	**Note**	
pre-1942	25	5	90	25x125 lot, house 20ft wide	
1942-1978	50	10	50		
post-1978	75	20	15		
Beds/Baths and Garage					
Group	**Garage**	**Bed**	**Bath**		
1	2 car attached	3	2.5		
2	2 car attached	3	2.5		
3	2 car attached	4	2.5		
4	2 car detached	3	1		
5	2 car attached	3	1.5		
6	2 car attached	4	2.5		
7	2 car detached	3	1		
8	2 car detached	4	2.5		
9	2 car attached	3	2.5		
10	2 car detached	3	1.5		
11	2 car attached	4	2.5		
12	2 car detached	3	1		
13	2 car detached	3	1.5		
14	2 car detached	3	1		
15	2 car detached	4	2.5		
Operation	**Setpoint Heating**	**Setpoint Cooling**	**MEL**	**MGL**	
pre-1942	70	72	Baseline (1.0)	Baseline (1.0)	
1942-1978	70	72	Baseline (1.0)	Baseline (1.0)	
post-1978	70	72	Baseline (1.0)	Baseline (1.0)	
	Misc HW Loads	**Natural Ventilation**			
pre-1942	Sink Aerators	Benchmark			
1942-1978	Sink Aerators	Benchmark			
post-1978	Sink Aerators	Benchmark			

As-built					
Walls/Ceilings/Roofs					
Brick	**(outside to inside)**				
Wall construction					
pre-1942	4 inch brick, 1 inch airspace, 4 inch brick, 1 inch lath (no insulation), 5/8 drywall				
1942-1978	4 inch brick, 1 inch airspace, 4 inch brick, 1 inch lath (R3 fiberglass), 5/8 inch drywall				
post-1978 (no CMU)	4 inch brick veneer, 1/2 inch wood sheathing, 2x4 stud wall with R-11 insulation, 1/2 drywall				
Frame					
Wall construction					
pre-1942	white wood siding, 1/2 inch wood sheathing, 2x4 stud wall no insulation, 5/8 inch drywall				
1942-1978	white wood siding, 1/2 inch wood sheathing, 2x4 stud wall R7 insulation, 5/8 inch drywall				
post-1978	white wood siding, 1/2 inch wood sheathing, 2x4 stud wall with R11 insulation, 1/2 inch drywall				
Insulation				**Interzonal**	**Interzonal**
Levels	**Brick Wall**	**Frame Wall**	**Ceiling Insulation**	**Walls**	**Floors**
pre-1942	0	0	0	0	0
1942-1978	3	7	11	7	11
post-1978	Brick vnr+R11 stud	11	30	11	19
Foundation/Floors	**Basement**	**Crawl**	**Slab**		
pre-1942	uninsulated	unin/ventil			
1942-1978	uninsulated	unin/ventil	uninsulated		
post-1978	uninsulated	unin/ventil			
Windows & Shading					
pre-1942	Double Clear (window+storm)				
1942-1978	Double Clear (window+storm)				
post-1978	Double Clear (window+storm)				
Air Flow	**Infiltration**	**Infil. - 2 story**	**Mechanical Ventilation**		
pre-1942	Very Leaky	Leaky	None		
1942-1978	Leaky	Typical	Spot		
post-1978	Typical	Tight	Spot		
Major Appliances	**Dryers**				
pre-1942	none				
1942-1978	gas				

As-built					
post-1978	gas				
Space Conditioning					
Heating (gas)	**System**	**Ducts**			
pre-1942	boiler 65%	None			
1942-1978	forced air 70%	Typical/uninsulated			
post-1978	forced air 78%	Typical/uninsulated			
Cooling					
pre-1942	none				
1942-1978	none				
post-1978	SEER 10				
Water Heating (gas)					
pre-1942	0.48				
1942-1978	0.48				
post-1978	0.49				

Today					
Building					
Lot size/dist to neighbor	**Size**	**Dist to Neighbor**	**Age**	**Note**	
pre-1942	25	5	90	25x125 lot, house 20ft wide	
1942-1978	50	10	50		
post-1978	75	20	15		
Beds/Baths and Garage					
Group	**Garage**	**Bed**	**Bath**		
1	2 car attached	3	2.5		
2	2 car attached	3	2.5		
3	2 car attached	4	2.5		
4	2 car detached	3	1		
5	2 car attached	3	1.5		
6	2 car attached	4	2.5		
7	2 car detached	3	1		
8	2 car detached	4	2.5		
9	2 car attached	3	2.5		
10	2 car detached	3	1.5		

Today					
11	2 car attached	4	2.5		
12	2 car detached	3	1		
13	2 car detached	3	1.5		
14	2 car detached	3	1		
15	2 car detached	4	2.5		
Operation	**Setpoint Heating**	**Setpoint Cooling**	**MEL**	**MGL**	
pre-1942	70	72	1.5	Baseline (1.0)	
1942-1978	70	72	1.5	Baseline (1.0)	
post-1978	70	72	1.5	Baseline (1.0)	
	Misc HW Loads	**Natural Ventilation**			
pre-1942	Sink Aerators	Benchmark			
1942-1978	Sink Aerators	Benchmark			
post-1978	Sink Aerators	Benchmark			
Walls/Clgs/Roofs					
Brick	**(outside to inside)**				
Wall construction					
pre-1942	4 inch brick, 1 inch airspace, 4 inch brick, 1 inch lath (no insulation), 5/8 drywall				
1942-1978	4 inch brick, 1 inch airspace, 4 inch brick, 1 inch lath (R3 fiberglass), 5/8 inch drywall				
post-1978 (no CMU)	4 inch brick veneer, 1/2 inch wood sheathing, 2x4 stud wall with R-11 insulation, 1/2 drywall				
Frame					
Wall construction					
pre-1942	white wood siding, 1/2 inch wood sheathing, 2x4 stud wall no insulation, 5/8 inch drywall				
1942-1978	white wood siding, 1/2 inch wood sheathing, 2x4 stud wall R7 insulation, 5/8 inch drywall				
post-1978	white wood siding, 1/2 inch wood sheathing, 2x4 stud wall with R11 insulation, 1/2 inch drywall				
Insulation				**Interzonal**	**Interzonal**
Levels	**Brick Wall**	**Frame Wall**	**Attic Insulation**	**Walls**	**Floors**
pre-1942	0	0	7 Blown	0	0
1942-1978	3	7	19 Blown	7	11
post-1978	Brick vnr+R11 stud	11	30	11	19

Today					
Foundation/Floors	**Basement**	**Crawl**	**Slab**		
pre-1942	uninsulated	unin/ventil			
1942-1978	uninsulated	unin/ventil	uninsulated		
post-1978	uninsulated	unin/ventil			
Windows & Shading					
pre-1942	Double Clear (window+storm)				
1942-1978	Double Clear (window+storm)				
post-1978	Double Clear (window+storm)				
Air Flow	**Infiltration**	**Infiltr - 2 story**	**Mechanical Ventilation**		
pre-1942	Very Leaky	Leaky	None		
1942-1978	Leaky	Typical	Spot		
post-1978	Typical	Tight	Spot		
Major Appliances	**Dryers**				
pre-1942	gas				
1942-1978	gas				
post-1978	gas				
Space Conditioning					
Heating (gas)	**System**	**Ducts**			
pre-1942	boiler, 80% AFUE	None			
1942-1978	Furnace 78% AFUE	Typical/uninsulated			
post-1978	Furnace 80% AFUE	Typical/uninsulated			
Cooling					
pre-1942	SEER 10 - window units				
1942-1978	SEER 10				
post-1978	SEER 10				
Water Heating					
pre-1942	0.54				
1942-1978	0.54				
post-1978	0.54				

Special Cases	
Group 1	Median built 1990 - increase walls by 1" foam sheathing, infiltration to tight, and ceiling to R38.
Group 4	Slab construction fit. Changed to floored attic, R19 (42-78) in roof for both As-built and today.
Group 7	Bungalow with upper half story. Added floored attic, no insulation (pre-42). R0 interzonal walls.
Group 11	MEL = 2 to match electric load (lakefront mansion).
Group 14	Only building with full/unfinished attic. Added floored attic As-built and flooring + R3 roof for today.

Upgrade (options evaluated by BEopt)					
Insulation				**Interzonal**	**Interzonal**
Levels	**Brick Wall**	**Frame Wall**	**Attic Insulation**	**Walls**	**Floors**
pre-1942			R30 or 38 blown		
1942-1978			R30 or 38 blown		
post-1978			R30 or 38 blown		
Space Conditioning					
Heating (gas)	**System**				
pre-1942	Boiler - 95% AFUE				
1942-1978	Furnace - 92.5% AFUE				
post-1978	Furnace - 92.5% AFUE				
Cooling					
pre-1942					
1942-1978	SEER 13				
post-1978	SEER 13				
Water Heating					
pre-1942	Premium (0.67EF)				
1942-1978	Premium (0.67EF)				
post-1978	Premium (0.67EF)				

Appendix III – Detailed Results Tables

BEopt results are presented in this appendix in the same format as the data in Appendix I in order to compare CNT data with modeling results.

			Square Footage		
GROUP	N Obs	% of Population	BEopt	CNT Mean	Dev, %
1	10856	2.5%	1740	1741	0%
2	8417	1.9%	1404	1404	0%
3	20530	4.7%	2500	2506	0%
4	77435	17.9%	1196	1217	-2%
5	26445	6.1%	1304	1299	0%
6	20755	4.8%	2064	2059	0%
7	50239	11.6%	1140	1141	0%
8	17629	4.1%	1872	1884	-1%
9	7318	1.7%	1800	1801	0%
10	9225	2.1%	1342	1349	-1%
11	4544	1.1%	3168	3178	0%
12	101957	23.6%	1176	1185	-1%
13	16411	3.8%	1584	1586	0%
14	48365	11.2%	1248	1254	0%
15	12479	2.9%	2064	2058	0%

	Source EUI (kBtu/SF)					
GROUP	BEopt, As Built	BEopt, Today	CNT Mean	Dev, %	BEopt Upgrade	Savings %
1	127.3	132.7	126.2	5%	125.7	5%
2	156.7	164.1	176.1	-7%	153.0	7%
3	117.6	118.7	120.2	-1%	108.2	9%
4	179.0	196.4	192.3	2%	181.6	8%
5	189.1	195.1	198.2	-2%	176.6	9%
6	141.5	155.2	147.7	5%	137.9	11%
7	216.2	224.7	227.8	-1%	182.6	19%
8	199.3	177.1	169.3	5%	141.4	20%
9	126.3	132.0	135.7	-3%	124.4	6%
10	242.1	193.9	199.1	-3%	157.9	19%
11	111.9	111.8	114.0	-2%	102.1	9%
12	181.5	191.0	199.0	-4%	170.4	11%
13	154.0	163.9	172.0	-5%	145.7	11%
14	222.5	216.4	222.9	-3%	154.8	28%
15	190.4	168.6	164.8	2%	131.7	22%

	Therms (100kBtu)					
GROUP	BEopt, As Built	BEopt, Today	CNT Mean	Dev, %	BEopt Upgrade	Savings %
1	1230.5	1161.5	1077.0	8%	1052.6	9%
2	1217.1	1146.5	1205.0	-5%	1014.9	11%
3	1473.9	1502.9	1446.0	4%	1279.6	15%
4	1290.5	1215.7	1212.0	0%	1064.9	12%
5	1597.5	1350.6	1344.0	0%	1143.6	15%
6	1865.7	1712.9	1553.0	10%	1405.6	18%
7	1676.7	1430.6	1442.0	-1%	1017.9	29%
8	2699.8	1940.9	1757.0	10%	1355.6	30%
9	1289.1	1209.5	1217.0	-1%	1084.5	10%
10	2366.8	1473.6	1480.0	0%	1047.0	29%
11	1696.6	1706.0	1749.0	-2%	1436.6	16%
12	1334.5	1204.6	1268.0	-5%	1005.6	17%
13	1544.5	1395.6	1467.0	-5%	1161.5	17%
14	1950.7	1578.7	1608.0	-2%	928.9	41%
15	2854.9	2034.9	1913.0	6%	1379.6	32%

	kWh					
GROUP	BEopt, As Built	BEopt, Today	CNT Mean	Dev, %	BEopt Upgrade	Savings %
1	7594.0	9074.7	8887	2%	9051.2	0%
2	7587.9	9159.2	10076	-9%	9059.9	1%
3	11577.9	11607.5	12482	-7%	11455.1	1%
4	6373.8	9254.1	8859	4%	9120.9	1%
5	6285.0	9227.1	9643	-4%	9102.6	1%
6	7692.5	11533.5	11714	-2%	11366.2	1%
7	5522.9	8724.6	8927	-2%	8468.5	3%
8	6817.1	10607.6	11062	-4%	10308.0	3%
9	7542.6	9203.6	9719	-5%	9203.6	0%
10	5791.1	8771.6	9321	-6%	8600.0	2%
11	14743.0	14733.4	14914	-1%	14588.0	1%
12	5902.6	8256.8	8483	-3%	8021.7	3%
13	6554.1	9367.3	9802	-4%	9074.7	3%
14	5637.0	8624.4	9050	-5%	8075.7	6%
15	7076.7	10869.8	11348	-4%	10488.3	4%

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