CEE HOME ENERGY IMPROVEMENT INDEX

Methods and early field experience

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CEE Home Energy Improvement Index: Methods and Early Field Experience

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Overview

The Center for Energy and Environment (CEE) developed the Home Energy Improvement Index for use with residential energy efficiency programs, specifically targeting cost-effective retrofits for existing homes. Its purpose is to help encourage major building envelope and heating plant energy upgrades by providing homeowners with a user-friendly and quantitatively robust indication of their home's current status and potential for major energy upgrades, as well as how to prioritize those upgrades.

The Energy Index summarizes results in a way that is easy to read and signifies clear action steps. It differs from similar scoring systems in that it is based on how close a home is to its cost-effective efficiency potential based on home style and age, rather than how it performs compared to a spectrum of homes. This allows any home to receive a perfect score upon completing all recommended retrofits — a major, attainable goal to motivate action.

As of April 2013 CEE had delivered over 1,000 scores to single-family homes in Minneapolis and St. Louis Park. Figure 1 below presents a sample score card based on initial visits. The remainder of this report describes the scoring tool's approach, quantitative calculations behind point assignments, and CEE's early experience with pilot homes.

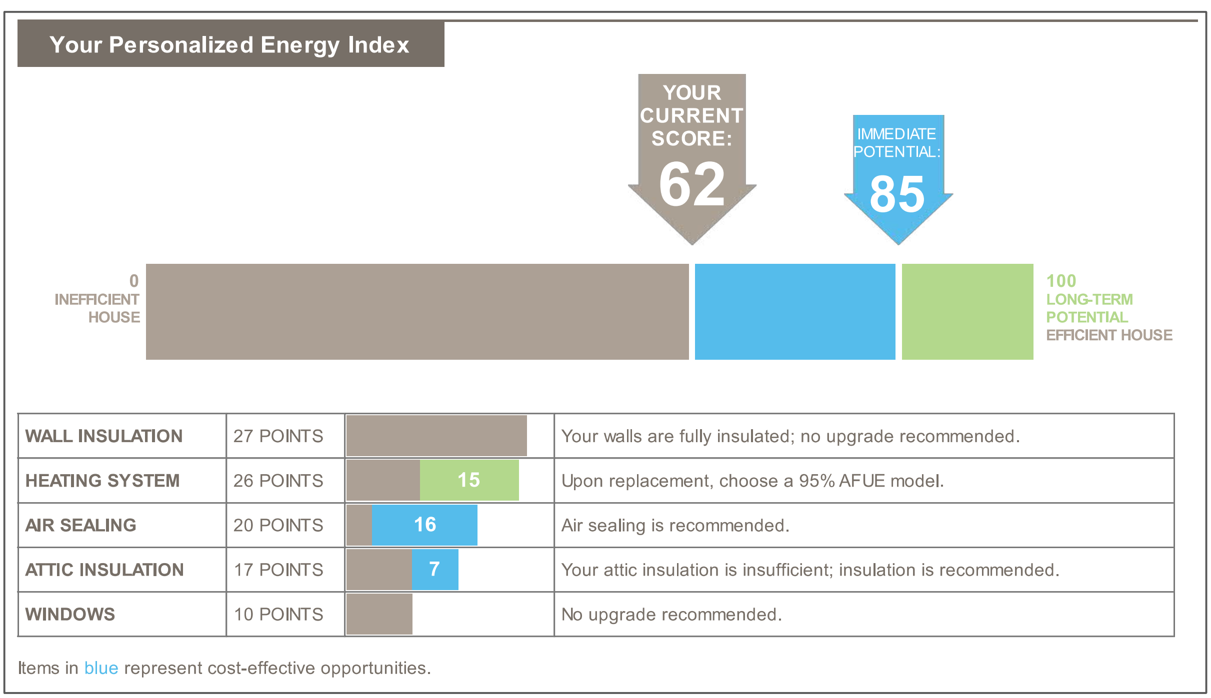


Figure 1. Sample CEE Home Energy Improvement Index

Motivation to Develop a New Tool

The primary motivator to develop the Home Energy Improvement Index (Energy Index) was to design a score tailored to the existing home retrofit market. Popular "green home" ratings such as LEED and the Home Energy Rating System (HERS) Index were designed to accommodate new home construction, and there are important differences between the approaches. For one, it is easier to collect data for a new home because time demands are lessened when a home is unoccupied, and a rater often has access to informative building plans. Also, the cost effectiveness of efficiency measures is maximized at the time new equipment is purchased. Finally, motivational tactics differ between a builder selling a new home and a resident improving their current home.

The Energy Index scoring method was designed to motivate audit participants to follow through with recommended upgrades. It supports the "kitchen table conversation" at the end of the home visit, where energy technicians connect with the homeowner to set priorities for moving forward. The Energy Index can motivate participants in multiple ways. Like a grade, it provides quantitative reinforcement of a home's current energy condition — rewarding good performance or indicating the necessity for improvement. Also, by weighting points according to potential energy savings, residents can readily prioritize their investments and avoid decision gridlock. And the Energy Index gives participants a psychological reward of a perfect score when they complete all cost-effective actions.

CEE designed and piloted the Energy Index for its single-family residential energy efficiency program, Community Energy Services (CES). Launched in 2009, CES is a whole-home audit program that provides direct installation of low-cost efficiency measures, recommends cost-effective energy retrofits, directs participants to preferred contractors to complete the work, and offers low- or no-interest financing for retrofits.[1] Through 2012, CES had conducted approximately 9,000 home energy visits in Minneapolis. In 2013 these program services were rolled into the umbrella of Xcel Energy's Home Energy Squad, with all services still provided by CEE.

Prior to launching the Energy Index, CEE conducted a field review of three building performance tools: the pilot version of DOE's Home Energy Score, the SIMPLE model, and RESNET's HERS Index.[2] The goal of this was to gain experience with the usability of existing residential energy performance models, and assess their ability to predict savings from retrofit upgrades. For Twin Cities housing stock, CEE found that more complex modeling did not provide a better prediction of an individual home's energy use, especially given the limited types of data that can be collected cost effectively during a home visit. Some data requirements were burdensome, especially those required to meet parameters for the modeling engine behind the HERS Index (the REM/Rate model), and some home characteristics were either time consuming to identify or hard to translate into the appropriate input fields. Even with the thorough data

[1] For more information see Nelson, Carl, "Energy Efficiency Cities: Using a Community-Based Approach to Achieve Greater Results in Comprehensive, Whole-House Energy Efficiency Programs." Available at http://mncee.org/Innovation-Exchange/Resource-Center/Technical-Reports
[2] Edwards, J.; D. Bohac; C. Nelson; and I. Smith. "Field Assessment of Energy Audit Tools for Retrofit Programs." NorthernSTAR Building America Partnership. September 2012.

collection conducted during the pilot, the predictive power of the energy modeling tools did not appreciatively increase.

This experience helped inform the quantitative design for CEE's Energy Index. In particular:

- The index is designed to minimize the time required for technicians to gather data in the field, thereby reducing the cost and burden of the energy visit on the homeowner. Prototype buildings are characterized in advance and fewer than 20 inputs about the home's current condition are required during the visit.
- The index uses a prescriptive approach for retrofit recommendations. The Minnesota version focuses on five upgrade areas that predictably cover the most cost-effective single-family retrofits: heating system, wall insulation, attic insulation, air sealing, and windows. Different geographic regions might pull in different priority measures, such as air conditioning or duct sealing.
- The index currently considers gas usage only, not electricity. This is because it is an asset score, meaning it focuses only on the building envelope and heating plant, not occupant behaviors such as thermostat set points or home electronics. Electricity use is highly driven by the number of occupants and their habits.[3] This choice to consider only gas usage is appropriate for buildings in Minnesota where air conditioning is a relatively small load and few homes have electric heat. If required, the score methodology can be adapted to incorporate additional source fuels.

The Energy Index Approach

The CEE Energy Index uses a 0-100 scale and indicates a home's current status and its score after immediate recommended upgrades are complete. Certain efficiency upgrades are recommended only when equipment needs to be replaced. The score itemizes the remaining points into individual actions. For the example, the home shown in Figure 1 scored a 62 and would receive an additional 16 points from air sealing and 7 from attic insulation, both of which were recommended to be completed immediately. In addition the home would receive 15 points from upgrading the heating system when it needs to be replaced, so that it would receive a perfect score of 100. All homes can receive a perfect score after all upgrades are completed.

The Energy Index scores a home based on how close it is to its full potential, rather than how it compares to other homes within the region. This way, a home's score is not limited by age or structural considerations. This is important for different home styles, particularly bungalow homes common to the Twin Cities since they have more limited attic space and can't insulate to the same level as a full one- or two-story home. It also ignores design features that influence energy use and are beyond the homeowner's control, such as window orientation or the size of the wall cavity. Older homes are not disadvantaged because they were built to a different code.

[3] Edwards et al 2012 found that the R^2 correlation between predicted and measured electricity use was 0.05 for the Home Energy Score pilot version, 0.24 for an asset-only SIMPLE application, and 0.30 for REM/Rate.

The level playing field is useful, but it also means this method does not offer a benchmark to compare widely across different types of homes. The importance of this tradeoff will depend on the application. For retrofits in existing homes, CEE determined that comparisons to other homes are less meaningful; most important is identifying retrofit opportunities and motivating homeowners to invest in them.

Quantitative Calculations

The Energy Index focuses on five key residential upgrade measures for Minnesota homes: heating system efficiency, wall insulation, attic insulation, air sealing, and windows. Based on CEE program experience and analysis, these prescriptive measures represent the primary cost-effective investments in the vast majority of Minnesota homes.[4] Other climates and housing stocks might include a different set of prescriptive measures. While new double-pane windows are often not cost-effective in Minnesota, homes will score lower if they have single-pane windows missing storm covers. By including windows, the score also helps communicate that this popular retrofit option should not be a high priority compared to other efficiency upgrades.

The CEE Energy Index uses a hybrid scoring approach that combines prescriptive recommendations with quantitative weighting of the energy savings from each measure. This is different from many residential scoring tools that model a home’s construction to estimate energy loads and then assign a score based on that output.[5] Instead, CEE defined eight prototype home styles common to Minnesota and modeled their energy systems to determine the relative importance of each efficiency measure for saving energy in that type of home. For instance, bungalow (story-and-a-half) homes have less attic space to insulate, so potential points from attic insulation are less than they are for a full two-story house.

The score for a specific home is determined based on its proximity to its full potential in each efficiency category. The outcome of this process is that staff can generate a score based on a small number of inputs about the home’s style and current efficiency condition, thus reducing the amount of data that needs to be collected during a home visit to approximately 20 inputs.

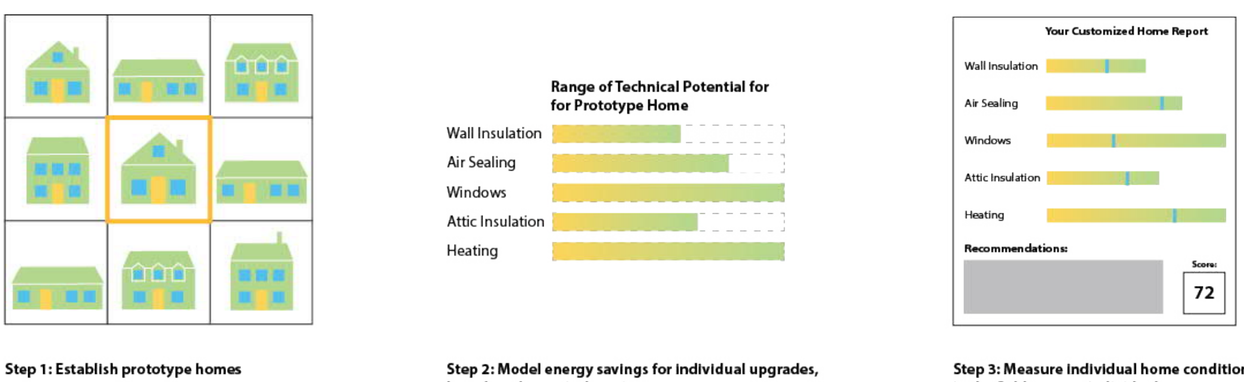


Figure 2. Quantitative Scoring Process for CEE Energy Index

[4] For this purpose, cost-effectiveness is defined as measures with simple paybacks under 10 years.
[5] For example, the HERS Index, the Home Energy Score, or the Energy Performance Score. These scores are based on REM/Rate, Home Energy Saver, and the SIMPLE model, respectively.

There are two important elements of a home score. The first is the total achievable points for each efficiency measure, which always sum to 100 but are distributed differently for each prototype house according to the relative energy saving contribution of each efficiency measure. The second is the individual measure score, which is calculated from the home's remaining cost-effective energy saving potential for each upgrade. Each of these elements is discussed in more detail below.

Total Achievable Points

CEE used the SIMPLE Model developed by Michael Blasnik and Associates to evaluate the energy savings of each measure for different home styles. Given that these energy measures are integrated parts of a home's thermal system, it is challenging to examine each one in isolation. For instance, the savings associated with an efficient heating system will depend on the amount of existing wall insulation, and additional attic insulation will also assist with air sealing needs. Therefore, individual energy savings were calculated by establishing "typical" conditions for a home and then modeling the energy savings between the low and high values for each measure individually. Table 1 shows these assumptions, with different home types noted where relevant.

Table 1. SIMPLE Model Input Assumptions for Weighted Savings of Efficiency Measures

Efficiency Measure	Typical Value	Low Value	High Value
Wall Insulation (R-Value)	R-7	R-5	R-11
Air Sealing (ALR)	1.25	2.0	0.85
Heating (AFUE)	80	70	95
Windows	Double Pane or Single Pane with Storm Windows	Single Pane	Double Pane or Single Pane with Storm Windows
Attic Insulation			
1 and 2 Story	R-20	R-10	R-50
1.5 and 2.5 Story	Peak: R-20 Kneewall: R-11.5 Slant: R-7 Sidewall: R-7 Floored Attic: R-12	Peak: R-5 Kneewall: R-5 Slant: R-5 Sidewall: R-5 Floored Attic: R-10	Peak: R-38 Kneewall: R-30 Slant: R-11 Sidewall: R-11 Floored Attic: R-50
1.75 Story	Peak: R-20 Slant: R-7 Sidewall: R-7	Peak: R-5 Slant: R-5 Sidewall: R-5	Peak: R-38 Slant: R-11 Sidewall: R-11

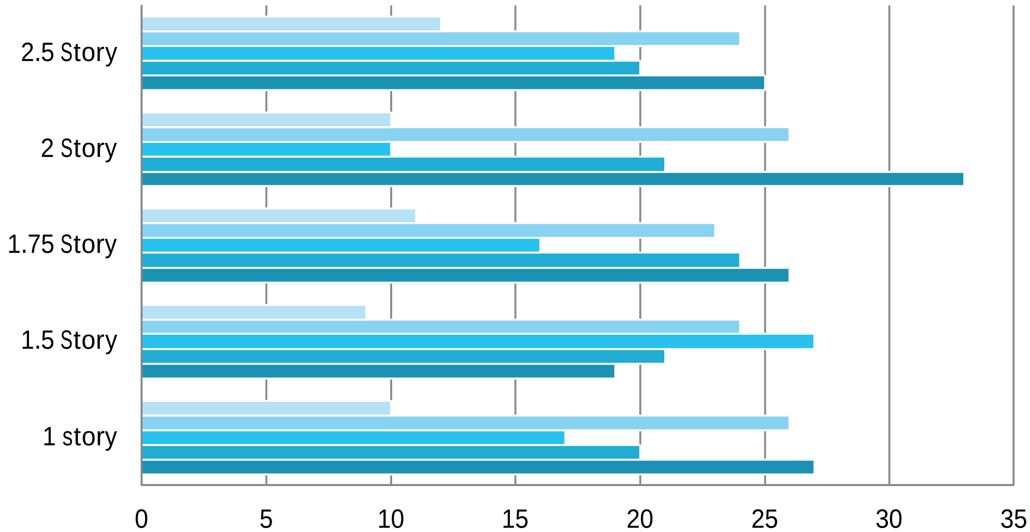
The table shows that the savings calculated for wall insulation equals the total energy use difference between R-5 and R-11, with all other measures held at their typical levels. Note that the lowest value represents the typical R-value of an empty wall construction and the highest value represents the recommended cost-effective upgrade for a given home type in Minnesota, not necessarily the highest physically attainable level.

Air sealing values were determined by analyzing trends in a database of over 7,000 Minnesota homes that had undergone insulation and air sealing upgrades as part the Minneapolis-St. Paul Metropolitan Airports Commission's sound insulation program, delivered by CEE. Each home had pre- and postretrofit inspections and blower door tests performed to verify performance improvements.[6] Heating system AFUE (annual fuel utilization efficiency) is assumed to range from 70 on the low end to 95 on the high end, CEE's recommended upgrade level for furnaces. Typical homes have a furnace system with an AFUE of 80.[7] Finally, total window points are calculated from the difference between a home with all single pane windows and a home with complete double-pane windows. Additional assumptions for the prototype homes are based on typical conditions for Minnesota housing stock.[8]

Attic and wall insulation efficiency measures are highly influenced by housing type. The current version of the SIMPLE model does not consider homes with partial floors (i.e., half stories), so the attic constructions of 1.5, 1.75, and 2.5 story homes were modeled using a modified version of SIMPLE to determine the energy savings of insulation upgrades. In this case, Table 1 shows the assumptions for the typical, low, and high insulation values for the different attic components, and the overall area weighted value are determined by piecing together the construction components for a specific style. This consideration makes a difference — the area-weighted high insulation values are R-20 for 1.5- and 2.5-story homes, and are R-12 for a 1.75-story home (compared to R-50 for a 1- or 2-story homes). Note that knee walls are considered part of the total attic space.

The figure on the next page shows the resulting point distribution for each home type. The total points for each sum to 100.

[6] Bohac, Dave and Marilou Cheple. "Ventilation and Depressurization Information for Houses Undergoing Remodeling." Prepared for the Minnesota Department of Commerce. October 2002.
[7] This number corresponds with data from homes that have participated in CEE's residential energy efficiency program.
[8] These include: the home has a gas water heater, a central air conditioning unit that is SEER 11, and no basement insulation (for a basement wall value of R-6).



	1 story	1.5 Story	1.75 Story	2 Story	2.5 Story
Windows	10	9	11	10	12
Heating System	26	24	23	26	24
Attic Insulation	17	27	16	10	19
Air Sealing	20	21	24	21	20
Wall Insulation	27	19	26	33	25

Figure 3. The total points for each of the five measures are fixed for a given style of home.

Individual Measure Score

A home's score depends on its current condition within the range defined by the low and high values for each efficiency measure. If a home is currently at or above its highest cost-effective state, it will receive all the points for that measure. Partial points are awarded in the following ways:

- Air sealing points depend on where a home's air leakage ratio falls between the high and low values, and are often awarded as partial points.
- Window points are awarded based on the percentage of windows that are double-paned or have storm windows.
- Attic insulation points are determined from the current area-weighted insulation value for the individual construction elements (e.g., knee wall, side attic, or peak).
- Heating systems receive partial points for an AFUE less than 95.
- Wall insulation points are "all or nothing" — that is, a home receives full points for R-11 when the walls are insulated. Exceptions include a home remodel where only a portion of the walls is insulated.

When a home scores below its full potential, the remaining points are classified as either "immediate" (ripe for an investment now) or "long-term" (better to wait for a remodeling opportunity). For example, if a heating system is reasonably efficient but not the most efficient, it is classified as a "long-term" opportunity to be timed with the system's eventual replacement.

Early Field Experience

The CEE Energy Index was integrated into program activities in St Louis Park and Minneapolis in April 2012. The results in Figure 4 refer to the 788 homes that received a score as part of their home energy visit that year. The distribution of home scores is shown in grey. The immediate potential is shown in blue, and their long-term potential (which always sums to 100) is shown in green. Fifty percent of homes scored a 71 or higher based on their home's current state. Homes in the 75th percentile scored an 83, and homes in the 90th percentile scored a 91. The minimum score was a 14, though only 2 percent of homes scored a 30 or below. Eleven homes, or 1.4 percent, scored a perfect 100.

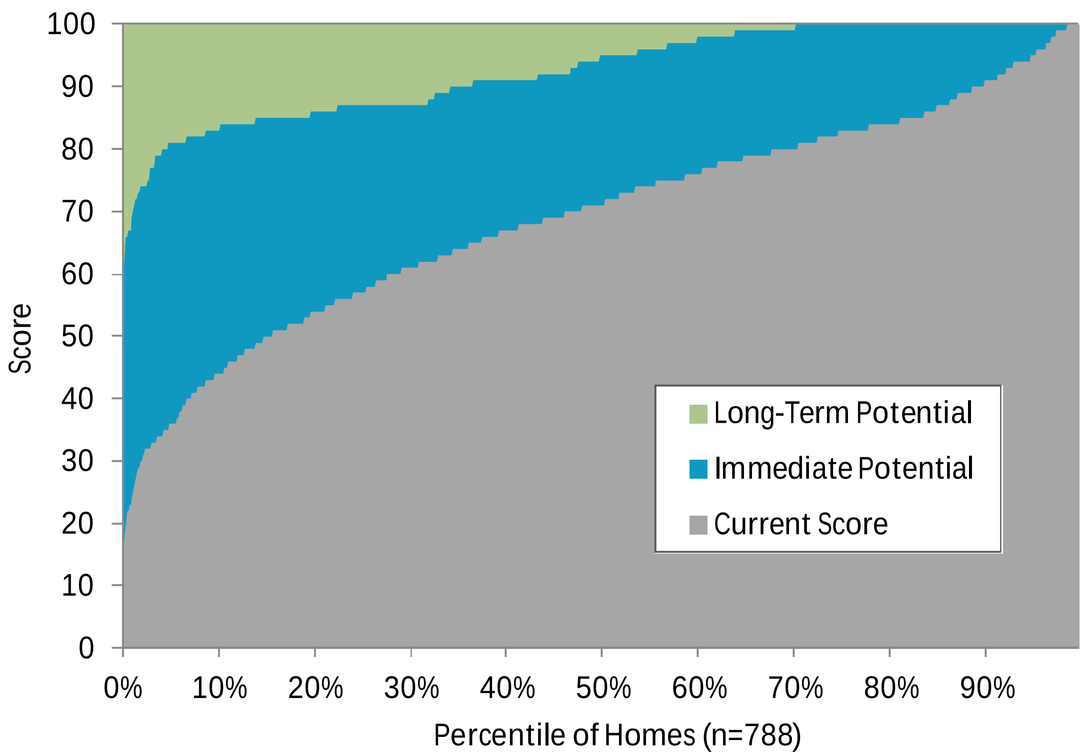


Figure 4. Distribution of Current Scores and Immediate Potential

The distribution of the immediate potential shows where homes can score by completing the measures that are immediately cost-effective. A large increase above the current score indicates a greater current opportunity for energy savings. The top 30 percent of all homes (the 70th percentile) can or did score a perfect 100 via immediate cost-effective improvements. The long-term points are recommended as future actions.

Figure 5 below shows how the remaining points to obtain a perfect score are distributed across the five different efficiency measures. For immediate timing, wall insulation holds the highest potential, followed by the heating system, air sealing, and attic insulation. Long-term, the dominant opportunity is upgrading to an efficient heating system upon replacement. Some long-term points are also available for wall or attic insulation, which would occur if a portion of the house lacks insulation that the homeowner is advised to upgrade upon remodeling. This figure also shows that 76 percent of the available points are available from immediate actions — and now or later, almost no points are available through window upgrades.

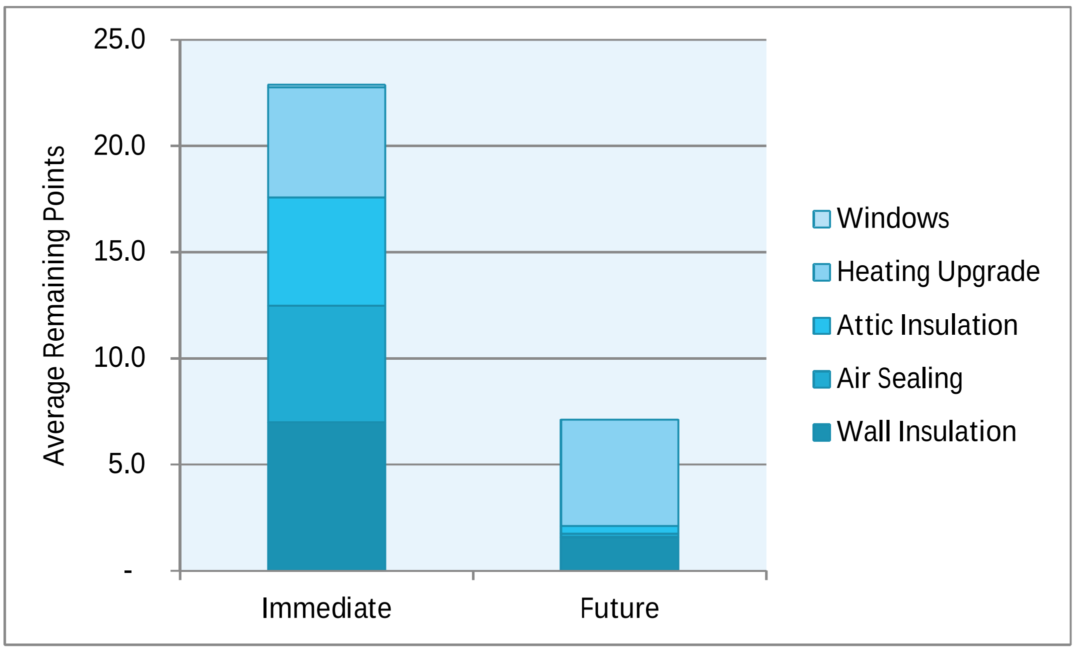


Figure 5. Average Remaining Points per home by Efficiency Measure

Figure 6 shows how the Energy Index varied across the different types of home. Each bin of scores (30-39, 40-49, etc.) is segmented according to the house styles that achieved that score. For example, of the 139 homes that initially scored between 60 and 69, 51 percent were 1.5 story homes. There is no indication that high or low scores are weighted toward a certain type of home. This aligns with one goal of the Energy Index — to avoid disadvantaging home styles that, due to structural limitations, have more limited potential to cost-effectively improve their home.

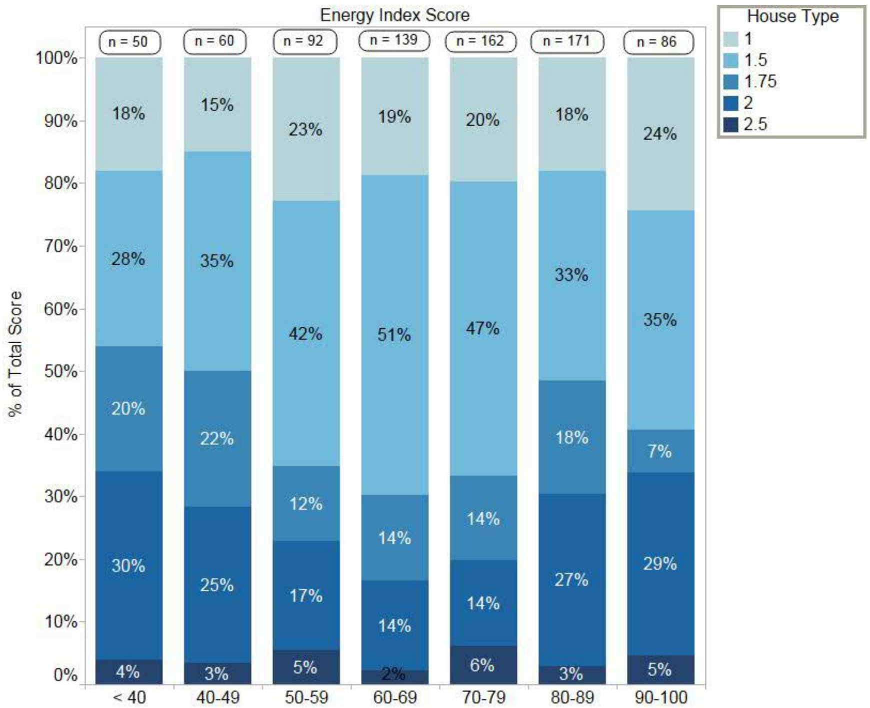


Figure 6. Distribution of Energy Index Results by House Style

Figure 6 shows the equivalent results, segmented according to the year of house construction. Unlike house style, there is a noticeable trend with older homes receiving lower Energy Index scores. Homes built before 1920 receive 56 percent of the scores below 40, and only 16 percent of the scores above 90. This is not due to structural conditions; these older homes have lower existing levels of wall and attic insulation.

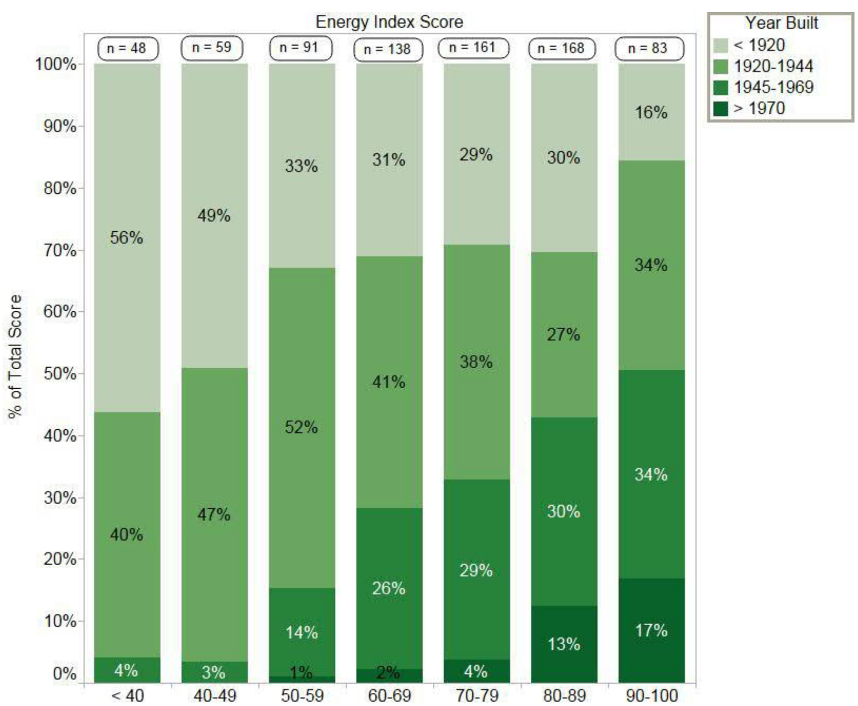


Figure 7. Distribution of Energy Index Results by House Construction Year

Finally, Figure 8 shows how the Energy Index results correlate with each home's measured gas use. Gas alone is considered because the Energy Index does not address electrical loads. Since the Energy Index does not score a home based on replicating its thermal loads, predicting a home's energy use is not an intended outcome. However, comparing actual energy use to a home's remaining cost-effective potential shows how the Energy Index relates to the full capacity for savings. Results show that homes with the lowest energy use (less than 3 therms/ft^2) all score well, which implies that these homes have completed most major upgrades to reduce their homes gas use by this much. However, homes with high use (over 7 therms/ft^2) have a range of scores, from less than 20 to over 80. This implies that the reasons for the highest use are not predictably structural, but have to do with other gas loads in the home.

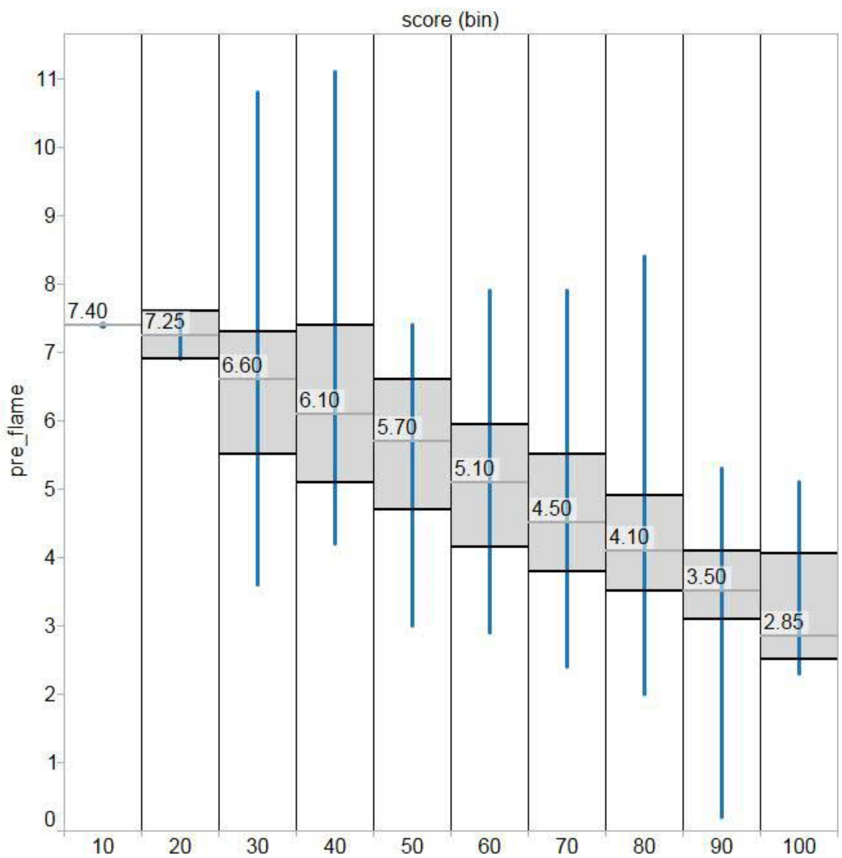


Figure 8. Gas Use Intensity and the CEE Energy Index

Summary

The CEE Energy Index is a quantitative home efficiency score that measures a home's cost-effective, thermal energy savings potential. The Energy Index was designed specifically for the home retrofit market, and builds off the key leverage points and roadblocks for homeowner motivation to upgrade an existing home. These include the desire for high attainment, avoiding paralysis by focusing on a small number of key upgrades and providing a clear path forward with ranked prioritization based on energy saving potential.

The Energy Index's distinct approach is to score a home based on how it measures up to its full potential, rather than how it compares to other homes. This allows homes with structural limitations, such as older bungalow homes with limited attic space, to avoid being penalized for a hard-wired feature that can't be changed. It also simplifies the amount of data that needs to be collected in the field by making use of modeled prototype homes that can be completed on the front end. The Energy Index requires approximately 20 diagnostic inputs and can be added to a whole-home energy assessment program at no additional cost.

Future work building off the CEE Energy Index will focus on rolling out a certification system for top-performing homes based on the technical methodology of the indexed scoring system.[9] Additional future opportunities include integrating this information at the time of home sales, leveraging a favorable window of opportunity when both buyers and sellers are more likely to invest in energy efficiency upgrades. The Energy Index methodology is advantageous for this application since it does not inherently disadvantage certain types of homes, a critical concern for the real estate market.

Delivering the Energy Index to 788 metro homes, CEE showed success improving communication and prioritization through "kitchen table conversations" following each home visit. Fifty percent of homes initially scored a 71 or higher, and the top 10 percent of homes scored a 91 or above. The specific measure recommendations mirrored the advice provided by field staff. Wall insulation holds the highest immediate potential, followed by the heating system, air sealing, and attic insulation. CEE also found that homeowners were not discouraged by the poor performance of an older home. There was no pattern to how scores distributed by house type. While older homes did have a higher percentage of low scores initially, their immediate potential was on par with homes of all ages.

[9] Since the time of this writing, CEE and partner organization the Neighborhood Energy Connection have launched Energy Fit Homes, the energy fitness score based on the index methodology. Homes that score above a 95 receive an Energy Fit designation. https://www.mncee.org/energy-fit-homes/home/