

DOE Challenge Home Label Methodology

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Background

The DOE Challenge Home is developing a label, to be applied to certified DOE Challenge Homes, which accomplishes two things:

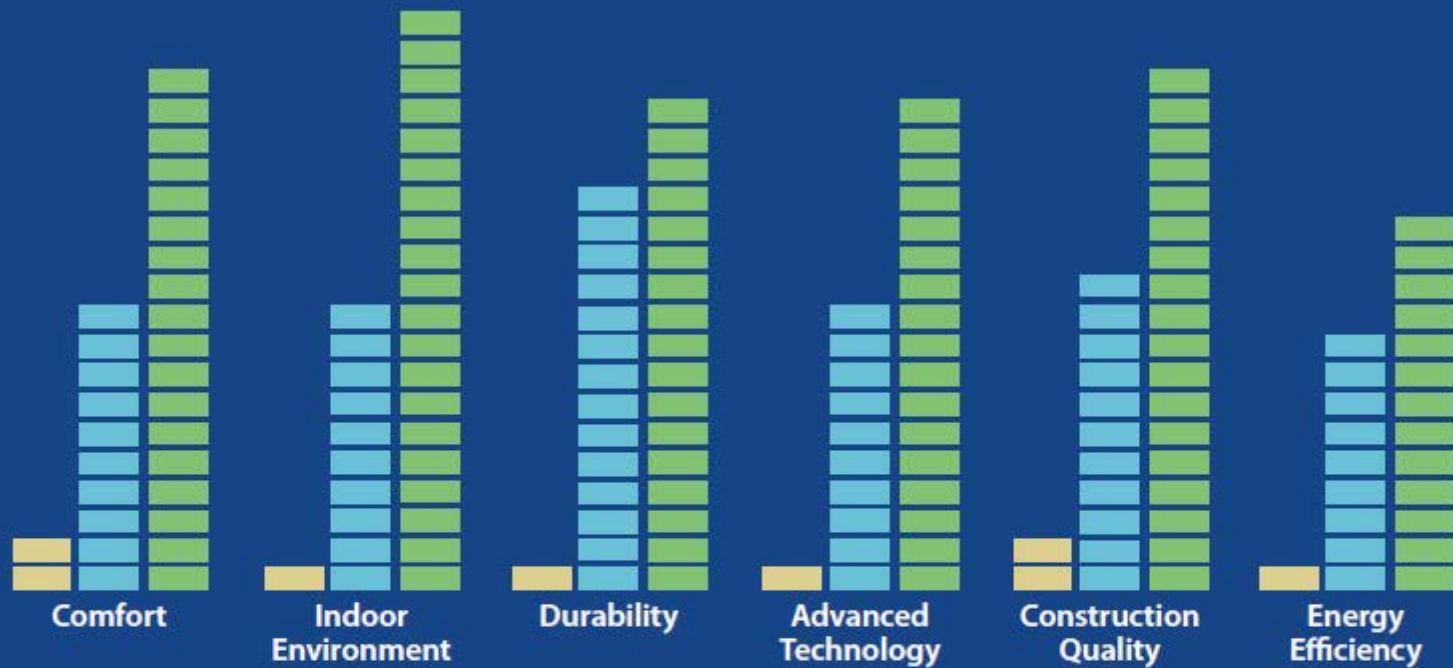
1. Identifies the home as a certified DOE Challenge Home
2. Conveys the core value messages of the DOE Challenge Home

The model for the label compares building science and quality measures of a DOE Challenge Home in six major categories to both an ENERGY STAR V3 certified home and an existing home. The following document describes the process used to develop the comparison, methodology used, and any assumptions made. Trying to compare the actual performance of these different construction levels would be difficult if not impossible – especially considering the fact that while minimum compliance can be defined, homes may surpass those minimums. In addition, existing homes is such a broad and varied group that trying to establish performance numbers that work for the whole population would be difficult. Therefore, this methodology focuses on comparing the number of measures in individual categories that a minimally compliant home would employ to achieve the category goals. The methodology is intended to estimate the relative number of measures implemented at each construction level in each of six categories:

- Comfort/Quiet
- Healthy Environment
- Enhanced Durability
- Advanced Technology
- Quality Construction
- Energy Efficiency

Each section described in the methodology below identifies what provisions should be counted in the estimate and what sources should be used for the comparison. The following graphic is an initial representation of the label concept.

DOE Challenge Home: A New Level of Performance



KEY

- DOE Challenge Home
- ENERGY STAR Home
- Existing Home

This label indicates relative performance of this DOE Challenge Home to recent vintage existing homes and ENERGY STAR qualified homes. Actual performance may vary.



Figure 1. DOE Challenge Home Label

Methodology

For each category below a the number of measures included in a DOE Challenge Home, and ENERGY STAR V3 home, and an existing home are compiled. In addition, for each category, measures beyond the DOE Challenge Home level are counted in order to get a total potential count for that category. The count for each home type is then compared relative to the total potential count for each category. The top level is measured in 20 units in each category, and the number of measures is converted to fit within that 20-unit scale. Any time a count resulted in a decimal, the number was rounded up or down as appropriate.

For the DOE Challenge Home level, requirements of the program related to the specific category are counted. The same methodology is used for the ENERGY STAR V3 home. For the existing home, energy measures were evaluated using the 1993/1995 CABO Model Energy Codes. A copy of the 1993 MEC was not available so a copy of the 1995 MEC, in addition to analysis showing the difference between these codes, was used. For the ENERGY STAR V3 home, measures included in minimum code (2009 IECC/IRC) are taken into account when compared to measures found in the DOE Challenge Home requirements (CO alarms is an example).

Non-energy measures for the existing home (such as moisture control) were taken from the 1992 CABO One- and Two-Family Dwellings Code. This early-mid 1990s home was chosen with the assumption that consumers in the market considering the purchase of a new home might also consider an existing home, but they are unlikely to be considering a 100-year old home next to a new build. The top potential level references major residential construction certification programs that go beyond DOE Challenge Home measures. In some cases these include programs that DOE Challenge Home encourages. In others, these include programs from which DOE Challenge Home only requires some measures.

In all cases, efforts were made to determine whether a home in a construction level would have a measure from another construction level for some other reason. For example, if one category counts advanced appliances, the existing home construction level is analyzed for levels of advanced appliances to be expected as these items are replaced in a home.

In all cases, the focus of this analysis is on capturing the measures found in a minimally compliant home for a given construction level. This analysis is not meant to suggest that a home certified under the ENERGY STAR V3 requirements could not also meet the DOE Challenge Home requirements. In fact, by nature of the mandatory requirement that all DOE Challenge Homes are ENERGY STAR V3 homes, there are many ENERGY STAR V3 homes that will perform at DOE Challenge Home levels. Likewise, the Existing Home may be built beyond code and include some of the measures and innovation of homes certified under either program. The label presents a comparison of minimally compliant homes.

Comfort/Quiet

This category focuses on thermal comfort measures, construction details which dampen sound transmission, air sealing, air distribution, and hot water distribution as components of comfort built into a home.

DOE Challenge Home: In order to count the items in a DOE Challenge Home that relate to comfort and quiet, items such as high quality insulation, windows, and air sealing are counted. The focus is to

capture both quantity and quality of thermal comfort measures, as well as other comfort measures. Several DOE Challenge Home National Program Requirements are counted, including mandatory items #3 (ducts in conditioned space) and #4 (efficient hot water distribution), in addition to air infiltration levels in Exhibit 2. Lower levels of air infiltration are considered as a comfort measure because of reduction in drafts and better thermal comfort.

Mandatory Item #3 (duct location) is counted as two measures to show the difference in the ENERGY STAR V3 requirement which allows ducts outside of conditioned space if they are tested to a certain air tightness level. Air infiltration is counted as two measures because DOE Challenge Home allows half the air leakage of an ENERGY STAR V3 home. Like ENERGY STAR V3, DOE Challenge Home gains credit for one measure for insulation installation quality requirements. Two measures will be added for DOE Challenge Home which has a minimum of 2012 IECC insulation levels to recognize the additional comfort achieved beyond 2009 IECC requirements. Likewise, DOE Challenge Home is credited with 2 measures for requiring ENERGY STAR qualified windows. Finally, the Thermal Enclosure System Rater Checklist provides credit for a final measure. Although several items noted above overlap with this checklist, credit for one measure is given because of the quality assurance that an inspection adds.

ENERGY STAR V3 Home: The ENERGY STAR V3 home measures also include the Thermal Enclosure Checklist, one measure for quality insulation installation, one measure counted for duct testing, and one measure for requiring envelope airtightness at twice as high as DOE Challenge Home levels. The 2009 IECC insulation levels are credited with one measure. ENERGY STAR (through the Thermal Enclosure Checklist) allows an option of ENERGY STAR windows or the 2009 IECC window minimum. This optional approach is credited with one measure.

Existing Home: For the Existing Home, some air sealing around lighting penetrations, as well as around windows and doors is included (MEC Section 502.3). Collectively these air sealing measures were given credit for 0.25 measures as they did not include comparable detail or rigor when compared to the Thermal Enclosure

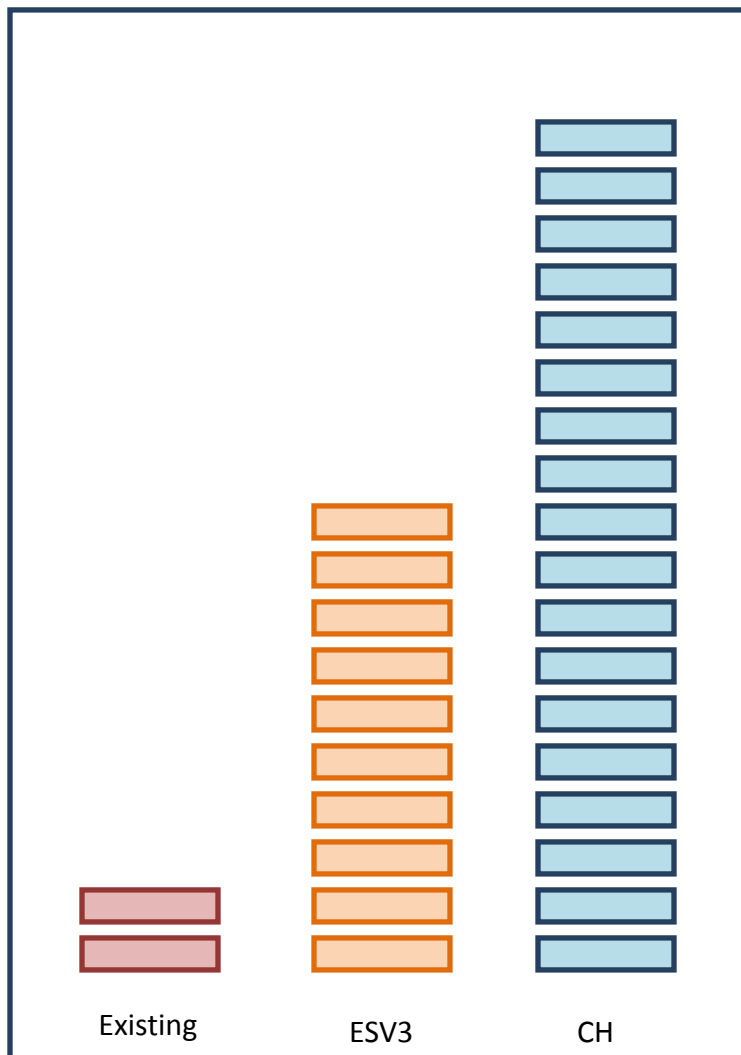
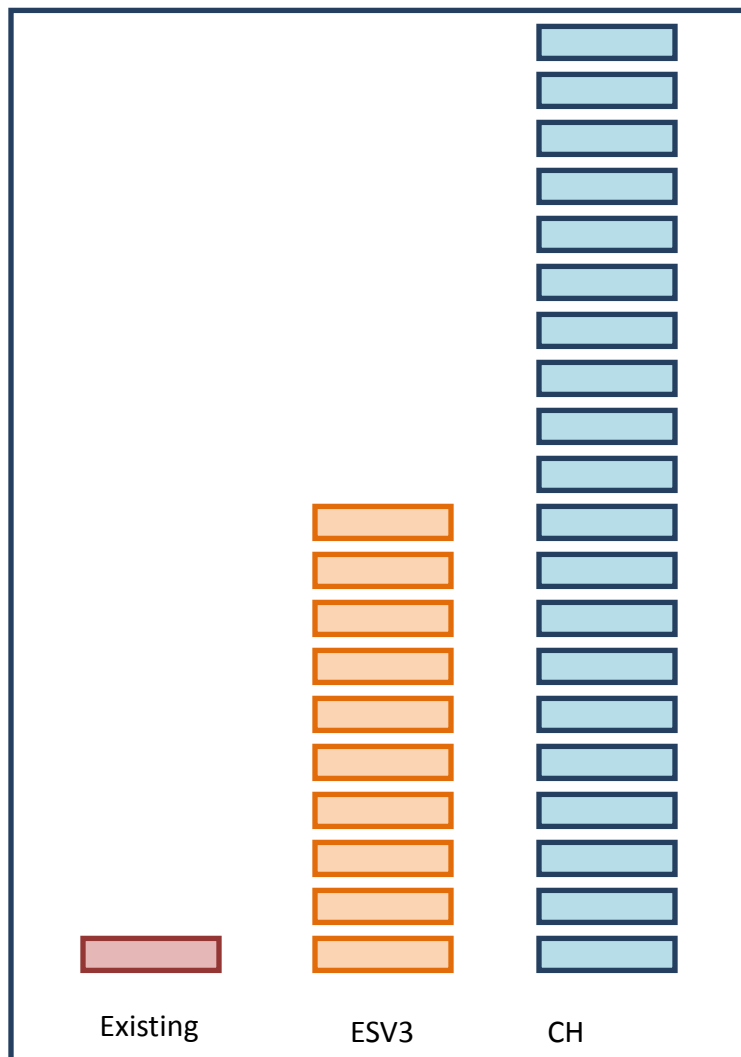


Figure 2. Comfort/Quiet

Checklist. In addition, this code includes some provisions for minimum insulation requirements, minimum window specifications, and some duct sealing requirements. Each of these items was credited as 0.25 measures.

Top Potential: One additional measure is added to the total score in recognition of the increased thermal comfort designed for homes meeting the Passive House Standard or similar levels of construction, including increased insulation and window efficiency.



Healthy Living

EPA's Indoor airPlus is a comprehensive, systems based set of specifications aimed at providing a healthy indoor healthy environment. Its focus on ventilation, moisture control, pollutant control, and testing is intended to provide improved indoor health.

DOE Challenge Home: For this exercise, the Indoor airPlus program has 37 measures, with the DOE Challenge Home including all measures.¹

ENERGY STAR V3 Home: ENERGY STAR V3 does not require Indoor airPlus. However, it allows the moisture control provisions (Section 1.1 to 1.13) of Indoor airPlus to be substituted for the EPA Water Management System. Therefore, these 13 measures are counted for the ENERGY STAR V3 Home. Several other measures required by ENERGY STAR V3 are equivalent or close to equivalent to other measures in Indoor airPlus. These requirements are found in the HVAC System Quality Installation rater and contractor checklists. The HVAC Rater checklist includes requirements for Manual J,

Figure 3. Healthy Living

Manual D, and local exhaust that approximate the requirements in sections 4.1, 4.2, and 4.6 of Indoor airPlus. Each of these equivalents is assigned credit for one measure. The rater checklist also requires a MERV 6 filter, where Indoor airPlus requires a MERV 8 filter. The MERV 6 filter is assigned credit for 0.5 measures. The HVAC Contractor checklist contains requirements for ASHRAE 62.2 ventilation that are roughly equivalent to section 4.5. This is assigned credit for one measure. In addition, Indoor airPlus

¹ Currently DOE Challenge Home allows exceptions on Section 2.2 and 5.6. However, both items, at the time of this report are under adjustment and DOE expects full alignment with the updated Indoor airPlus Specification

section 5.3 requires a CO alarm. Although ENERGY STAR does not require this provision, any home built to the 2009 IRC (Section R315) has essentially the same requirement found in the Indoor airPlus program. Therefore, the ENERGY STAR V3 home is credited with one measure in order to accurately account for the lack of differences related to CO alarms between homes built under either program.

Existing Home: The CABO code includes some language providing for foundation drainage (R301.3), as well as requirements for partial flashing of windows (R503.8). Although not as detailed or rigorous, these provisions deal with some of the same provisions in the Indoor airPlus moisture control section. Each provision is credited with 0.5 measures.

Top Potential: Full Indoor airPlus requirements are used as the total potential, with all 37 measures included.

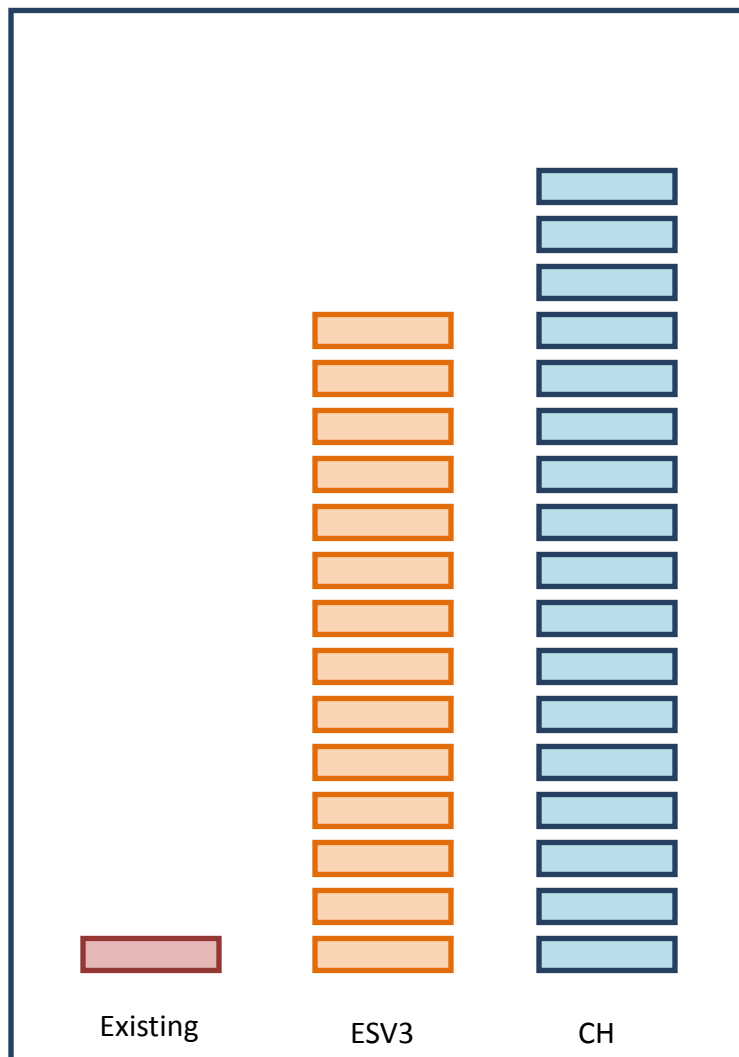


Figure 4. Enhanced Durability

Enhanced Durability

For enhanced durability, the label focuses on moisture protection measures, as well as the number of inspections that should ensure a better, more durable product with fewer needs for repairs at later dates. It also includes any measures that incorporate better building practices at construction that will avoid expensive retrofits later.

DOE Challenge Home: DOE Challenge Home counts the measures included in the Indoor airPlus Moisture control section. Although the EPA Water Management System Builder Checklist can be substituted, for consistency with the Healthy Living Section, this analysis counts the Indoor airPlus measures.

The other inspections or items that would prevent extensive future retrofit are counted as one measure each, and include the Thermal Inspection Checklist, the HVAC System Quality Installation Rater Checklist, the HVAC System Quality Installation Contractor Checklist, the blower door test, Renewable Ready Checklists, ducts in conditioned space, plus any inspections in minimum code homes.

In addition, the overall Indoor airPlus inspection is included as one measure. Ducts in conditioned space (which receives credit for 2 measures compared to duct testing required by ENERGY STAR) and Renewable Ready Checklists are examples of measures that, when implemented at construction, will

save a homeowner relatively costly renovation expenses should they wish to install these measures in the future. Although having tight ducts will save a homeowner future expense of having to seal those ducts, moving ducts inside conditioned space as a retrofit carries an even greater cost. Likewise, installing renewable system features in a home as a retrofit measure can be much more costly than installing these features at the time of construction.

ENERGY STAR V3 Home: Similar to the DOE Challenge Home, the ENERGY STAR V3 home also includes the moisture control sections of Indoor airPlus (in place of the Water Management System Builder Checklist) as 13 measures. In addition, the Thermal Inspection Checklist, the HVAC System Quality Installation Rater Checklist, the HVAC System Quality Installation Contractor Checklist, the blower door test and a duct blaster test, plus a code inspection are included as one measure each.

Existing Home: As in the Healthy Living Section, the foundation drainage (R301.3), as well as requirements for partial flashing of windows (R503.8) found in the CABO code is given credit for 0.5 measures, while code inspection is counted as one full measure. Code inspection was included in both other homes because, while it does enhance the durability of the Existing Home, it would also be included in a DOE Challenge Home or an ENERGY STAR Home.

Top Potential: The total potential was counted by adding in optional checklists/inspections that are encouraged, but not required by the DOE Challenge Program. These include IBHS's Fortified program, the DOE Quality Management Checklist, and the full EPA WaterSense inspection. One additional measure was added for the IBHS Fortified program to account for the additional disaster resistance required by that program.

Advanced Technology

For this category, the analysis focuses on the number of innovations and advanced systems required by the construction level in the form of mandatory items, prescriptive requirements, or checklists. Rather than focusing on individual components of checklists each checklist is counted as one innovation.

DOE Challenge Home: The measures counted for this home include:

- 2012 IECC Insulation Levels
- ENERGY STAR Windows
- Ducts in Conditioned Space
- Hot Water Distribution Efficiency
- Indoor Air Quality
- Beyond code lighting
- ENERGY STAR Appliances
- Renewable Ready PV Checklist
- Renewable Ready Solar Thermal Checklist
- Thermal Enclosure Checklist
- Indoor airPlus Moisture Control provisions/EPA Moisture Management System Builder Checklist
- Both HVAC Checklist Quality Installation Checklists
- Tight building envelope

2012 insulation levels are given credit for two measures, which allows the 2009 Insulation levels required by ENERGY STAR V3 to be counted as one measure. Ducts in conditioned space is counted as

two measures, which allows the duct testing requirement within ENERGY STAR V3 to count for a single measure. Similarly a tight building envelope is given two measures to account for the difference with ENERGY STAR V3.

ENERGY STAR V3: The measures counted for this home include:

- 2009 IECC Insulation Levels
- 2009 IECC Windows or ENERGY STAR Windows
- Tight Ducts
- Beyond code lighting
- ENERGY STAR Appliances
- Thermal Enclosure Checklist
- Indoor airPlus Moisture Control provisions/EPA Moisture Management System Builder Checklist
- Both HVAC Checklist Quality Installation Checklists
- Tight Building Envelope

Existing Home: Advanced technology and innovation by current standards would not be found in a home build 15-20 years in the past. However, in some cases, technology in the home would often be replaced with newer technology as it becomes available. A 2008 ACEEE report² shows the current market share of

ENERGY STAR refrigerators, close washers, and dishwashers.

Averaging these market shares together shows a market share of just over 50% ENERGY STAR Appliances. Therefore, the existing home is credited with 0.5 measures compared to the full measure required in the other two homes. Unlike appliances, lighting is not credited in the existing home. Although efficient lighting has gained market share in existing homes, the other two homes are only credited for beyond code lighting. No evidence is available that suggests that existing homes are introducing efficient lighting at levels beyond current code requirements (50% in the 2009 IECC and 75% in the 2012 IECC).

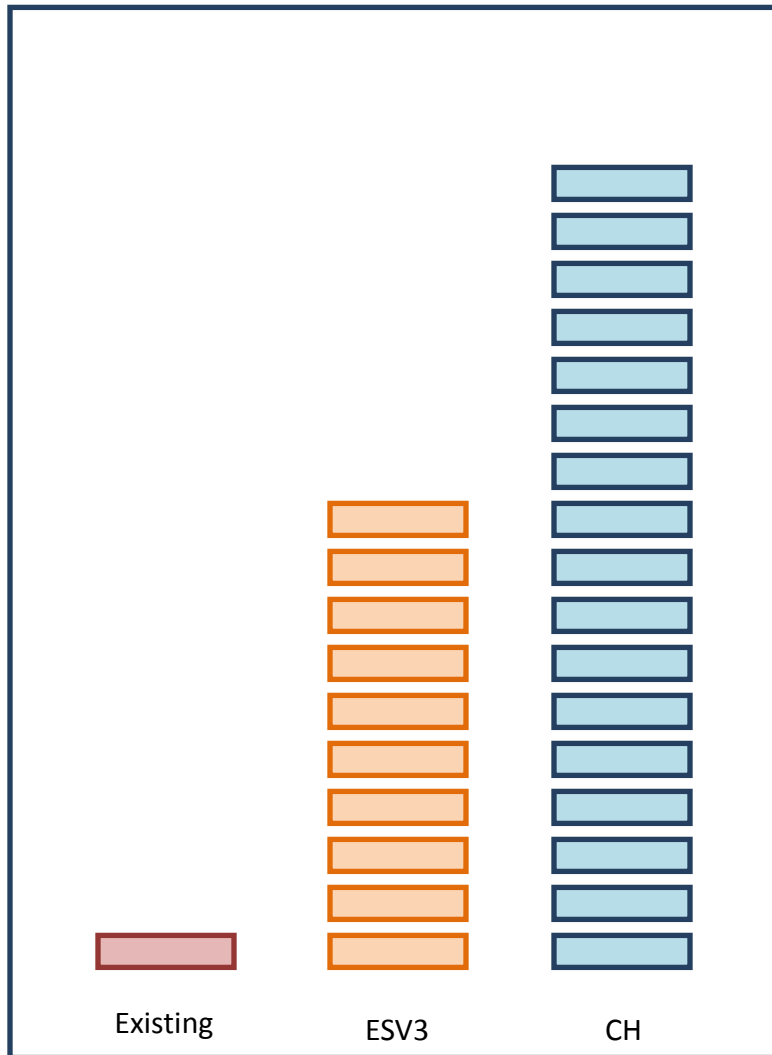


Figure 5. Advanced Technology

² D&R International. "Market Penetration of ENERGY STAR Qualified Appliances: An Analysis of Various Predictor Variables." Prepared for ACEEE Summer Study on Energy Efficient Buildings, 2008.

Top Potential: It is impossible to quantify all of the innovations that could go into a home. However, in order to establish the total potential, this analysis uses innovations included as recommendations in the DOE Challenge Home program, including R-5 windows, the IBHS Fortified program, and EPA’s full WaterSense program.

Quality Construction

Similar to the Enhanced Durability Section, this category focuses on the number of inspection and checklists needed for compliance, using inspection as a proxy for quality. Unlike Enhanced Durability, it does not focus on other measures that impact the need for future retrofit.

DOE Challenge Home: The inspections included for this home are:

- Indoor airPlus Moisture Control provisions/EPA Moisture Management System Builder Checklist
- Non Moisture Control Indoor airPlus inspection
- Renewable Ready PV Checklist
- Renewable Ready Solar Thermal Checklist
- Thermal Enclosure Checklist
- Both HVAC Checklist Quality Installation Checklists
- Code Inspection

ENERGY STAR V3 Home: The inspections included for this home are:

- Indoor airPlus Moisture Control provisions/EPA Moisture Management System Builder Checklist
- Thermal Enclosure Checklist
- Both HVAC Checklist Quality Installation Checklists
- Code Inspection

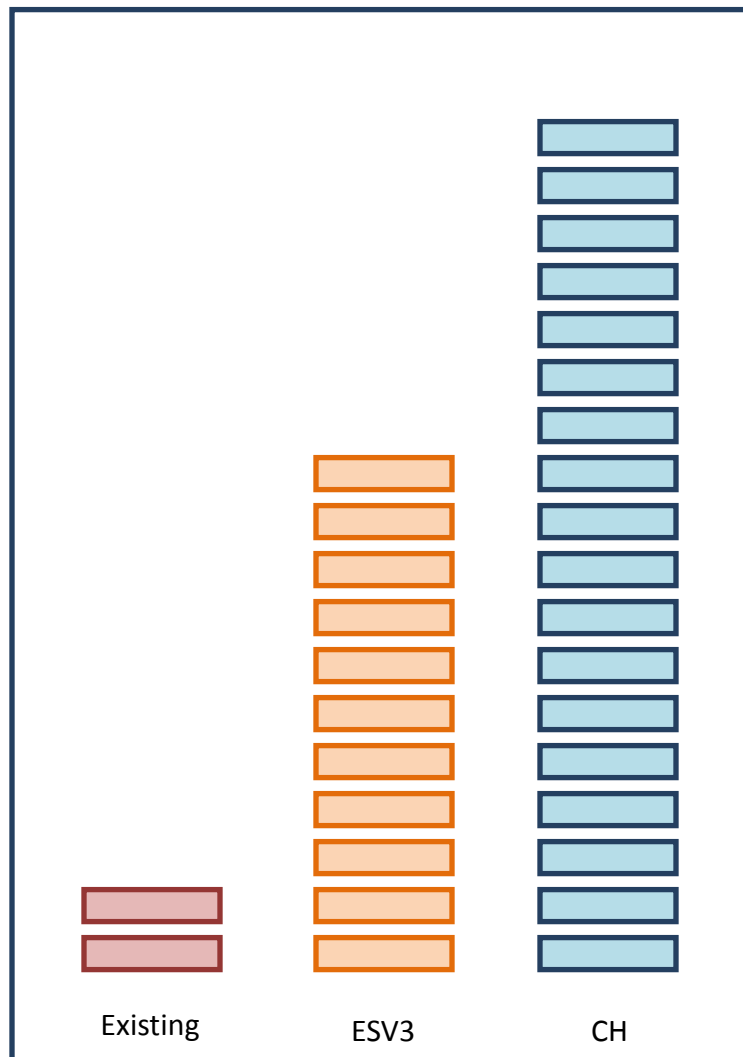


Figure 6. Quality Construction

Existing Home: This home only includes the code inspection as one measure.

Top Potential: In this case the DOE Quality Management Checklist which is recommended but not required is credited with one measure.

Energy Efficiency

The HERS rating system is a useful tool in comparing energy efficient homes to a code minimum. As a nationally used standard for rating the modeled energy performance of homes, and as an integral part of the certification process for both DOE Challenge Home and ENERGY STAR V3, it presents an ideal way to estimate energy efficiency in each home category. Unlike other categories where each measure is counted as one unit and then converted to a 20 point scale, the HERS Index for one construction level is compared to the HERS Index for another level, and the relative score is based on that comparison. Because the HERS Index scale uses zero as the best score, these scores needed to be reversed in order to fit into the label format. For each category the HERS Index is subtracted from 100, providing a scale

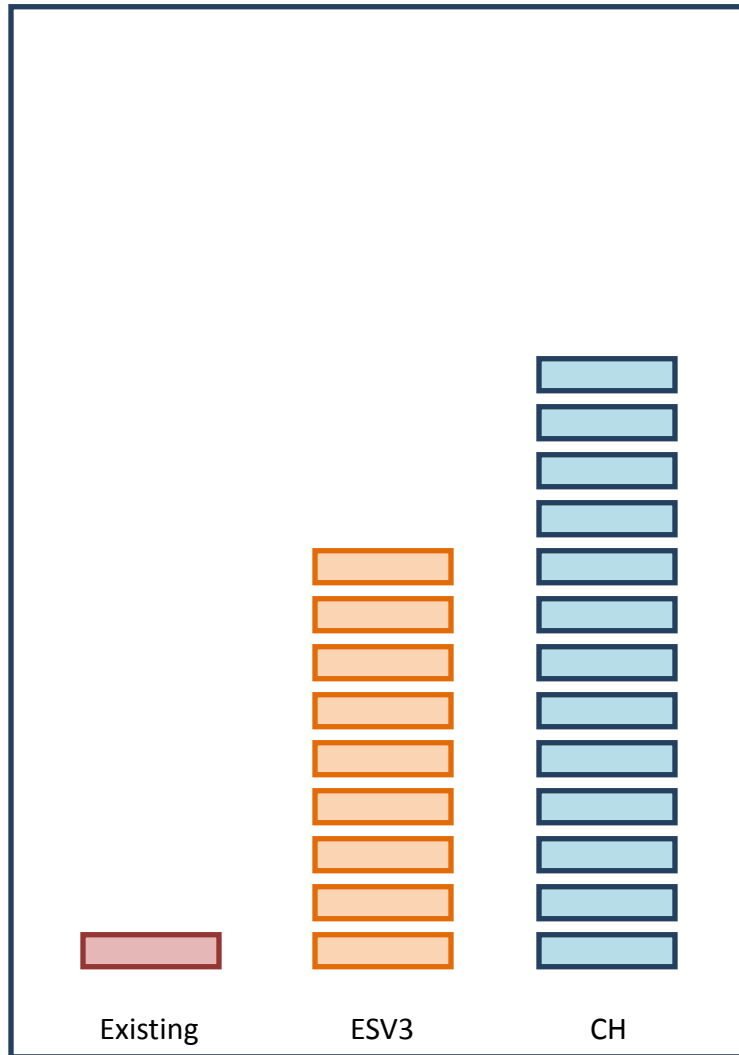


Figure 7. Energy Efficiency

that shows higher numbers as better. This method results in a negative score for the existing home. This effectively reversed the index so that it could be converted into the same bar units used in other categories. A score of 100 was used as the anchor for this scale reversal because the HERS Index is anchored by a reference home with a score of 100. Therefore the scale for all categories was shifted up in order to represent the existing home on the scale.

DOE Challenge Home: Initial Analysis has shown that across different climate zones, a minimally compliant DOE Challenge Home has an average HERS Index of 55, although this will vary based on size, climate, and building components used. This measure will represent the DOE Challenge Home level. The HERS 55 is based on analysis of prototype homes in climates 1-7. Climates 1-3 were modeled as electric homes, while climates 6-7 were modeled with gas space and water heating. In climate zones 4 and 5, homes were modeled as both gas/electric and electric-only to reflect market diversity. Prototypes of 1800, 2400, and 3600 sq ft. (not including

conditioned basements, where applicable) were modeled. For these prototypes the DOE Challenge Home Target Home prescriptive values were used, in addition to any mandatory requirements. After the scale was reversed the DOE Challenge Home had an effective score of 45 (or 45% better than the HERS reference home)

ENERGY STAR V3: The average HERS target for ENERGY STAR V3 Homes is around a HERS 68. To establish this average, prototypes were modeled using the ENERGY STAR V3 Reference Home prescriptive values, in addition to any other mandatory requirements. Prototypes in climate zones 1-7 were modeled, with the same methodology as used for the DOE Challenge Home modeling described above. One exception to this methodology: only the 2400 sq ft prototype was modeled. After the scale was reversed, the ENERGY STAR V3 Home had an effective score of 32 (or 32% better than the HERS reference home)

Existing Home: Some analysis is necessary to establish the HERS Index for the Existing Home. Due to the large age range, and lack of data on existing homes, there is no clear HERS index that will adequately characterize the modeled energy efficiency of all existing homes. Using the 1993 MEC as an energy efficiency target, this analysis is able to provide a reasonable HERS Index for homes built to that standard. For this analysis, the same general prototype home methodology used to analyze the DOE Challenge Home HERS target is used to determine the 1993 MEC HERS index. All Electric Homes were modeled in climate zones 1-3, while gas and electric homes (with gas heating and water heating) were modeled in climate zones 6 and 7. Climate zones 4 and 5 included 2 prototype homes each – one all electric and one gas and electric. The analysis was limited to 2400 Sq ft homes (not including conditioned basement square footage when appropriate).

HERS software provides reports on 1993 MEC compliance. For this exercise, 1993 envelope minimums were used along with other assumptions to establish a 1993 MEC home. These prototypes were then tested against the 1993 MEC compliance report. Due to the fact that the 1993 MEC compliance analysis in HERS does not include water heating, lighting, or appliances, several assumptions are made.

- Water heating efficiency based on 1993 efficiency minimums³
- Space heating and cooling efficiency also based on 1993 efficiency minimums⁴
- Ducts were assumed to be 100% in unconditioned attics for slab homes; ducts were assumed to be in conditioned space for homes with basements.
- Given the minimal duct sealing requirements in the 1993 MEC, ducts were assumed to be leaky (75% thermal efficiency for ducts in conditioned space; 70% thermal efficiency for ducts in unconditioned space)
- Lighting – 16% of sockets in a typical home have CFLs.⁵
- Lighting – 12% pin-based fluorescents⁶
- Window specs were informed using the ASHRAE Handbook of Fundamentals⁷
- Assumed RESNET Grade III insulation installation for all insulation
- 8.3 ACH50 assumed for envelope air leakage⁸

The average HERS Index across the prototype homes was a HERS 117. After the scale was reversed, the existing home had an effective score of -117 (or 17% worse than the HERS reference home). This would result in zero units being shown for the existing home. However, one unit was added to the existing

³ 10 CFR 430.32 as of Jan 1, 1993

⁴ Efficiency minimums as of Jan 1, 1993

⁵ D&R International. "ENERGY STAR CFL Market Profile." Prepared for the U.S. Department of Energy. September 2010

⁶ KEMA, Inc. "Final Evaluation Report: Upstream Lighting Program." Prepared for the California Public Utilities Commission, Energy Division. February 8, 2010, as cited in ENERGY STAR CFL Market Profile

⁷ 2009 ASHRAE Fundamentals Chpt 15, Table 10 and Table 4.

⁸ LBNL database

home in order to acknowledge that some systems or features on the homes may have been replaced over 15-20 years with more efficient systems or features.

Top Potential: Passive House, the energy efficient program that goes beyond DOE Challenge Home in energy efficiency has stated that a Passive House would reach a HERS 20-30. For this analysis, the potential target is placed at HERS 30.⁹ Clearly homes can achieve even lower HERS indices through renewable energy systems, but both DOE Challenge Home and ENERGY STAR V3 limit the ability to use renewable energy systems to meet the HERS target. After the scale was reversed, the top potential home had an effective score of 70 (or 70% better than the HERS reference home).

⁹ http://www.passivehouse.us/passiveHouse/Articles_files/passivehouse.pdf