Evaluating Residential Energy Efficiency Programs with a Universal Metric

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Since the oil crisis in the 1970s, building energy codes in the United States have begun mandating the construction of more energy efficient buildings. Improving the energy performance of buildings has proven to be a cost effective way to solve both fossil fuel depletion and energy security problems. More recently, adopting increasingly stringent energy building codes has been hailed as a key way to halt climate change. In 2008, buildings alone consumed 40 percent of US energy and 71 percent of US electricity.[1] Both governmental and non-governmental organizations have agreed that buildings, as the largest contributor to green house gases, need to be energy efficient. To achieve this feat, building codes have become stricter and energy efficiency programs, like the Department of Energy's Energy Star and the United States Green Building Council's LEED, have developed.[2] While codes are mandatory regulations, voluntary guidelines are followed by choice in addition to code. Voluntary programs encourage home owners and builders to exceed minimum code requirements, improve the energy performance of their homes, and help curb the negative effects of climate change.

Despite the creation of numerous energy efficiency building programs and the modification of energy building codes, a common metric and rating system to compare the effectiveness of all the programs does not exist. Many organizations have recognized the need to quantify the energy efficiency of their particular programs on a scale. However, rather than contributing to a universal and existing metric, organizations have instead devised separate metrics.[3] These metrics, although similar, have prevented the public from gaining a truly comprehensive understanding of the effectiveness of energy efficiency programs. Today, without a visual representation and comparison, it is easy for the building industry and homeowners to make uninformed design decisions. For instance, a contractor may know that Builders Challenge and Energy Star homes are more energy efficient than homes that only following code, but does not know that Builders Challenge homes are significantly more energy efficient than Energy Star homes. [4,5]

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[1] **Fay, William.** NASEO Annual Meeting. [Online] September 8, 2008. [Cited: 27 January, 2009.] http://www.naseo.org/events/annual/2008/presentations/Fay.pdf.
[2] *Architecture: Architets of a low-energy future.* **Butler, Declan.** s.l. : Nature News, 2008.
[3] Building America. [Online] http://www1.eere.energy.gov/buildings/building_america/
[4]Builders Challenge. *DOE.* [Online] May 20, 2008. [Cited: January 6, 2009.] from http://www1.eere.energy.gov/buildings/challenge/about.html.

Using the Residential Energy Services Network's Home Energy Rater Systems Index (HERS Index) as a metric, this paper will calculate the HERS Index numbers of current building programs and demonstrate the benefits of adopting a common system of measurement. Only through using a common metric, like the HERS Index, can residential building standards, model codes, codes, and voluntary programs be accurately compared and analyzed.

The HERS Index Explained

The Residential Energy Services Network (RESNET), a not-for-profit member corporation, initially developed the HERS Index "to measure the monetary savings attributable to the energy efficient features of a home with the goal of crediting the energy efficiency of a home in the mortgage loan."[6] Today the HERS Index is used to rate a building's energy performance.[7] To calculate the HERS Index number of a particular residence, an auditor considers a "home's heating and cooling efficiency, insulation levels, appliance and lighting energy use, window efficiency, a home's solar orientation, and other factors that are tailored to the home's climate regions."[8] Analyzing these building factors ideally helps homeowners and contractors realize home inefficiencies and invest in energy improvement technologies.

HERS Index numbers are quantified on a vertical scale. For practical reasons, a HERS Index usually ranges from about 130 at the top to -10 at the bottom. It should be noted, however, that a HERS Index number for a particular home could potentially range beyond 130 and -10 if a residence performs extraordinarily poorly or strongly. A home with poor energy performance earns a high HERS Index number, while a home with strong energy performance earns a low HERS Index number. A home with an Index number of 100, for instance, uses more energy than a comparable home with an Index number of 60.

Home Type (Index number)	Definition
Typical US home (130)	Built before 2006.
New home (100)	Complies with the 2006 International Energy Conservation Code (IECC) mandates.
Net-zero home with cogeneration (0)	Produces as much energy as consumed through a cogeneration system such as solar panels.

Table 1: Home Type Definitions

[5] What's a HERS score. *Energy Star.* [Online] http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_HERS
[6] About RESNET. *Residential Energy Services Network (RESNET).* [Online] http://www.natresnet.org
[7] Introducing RESNET - The American Building Performance Rating System. *RESNET.* [Online] [Cited: January 26, 2009.] http://www.resnet.us/about/resnet.htm.
[8] Introducing RESNET - The American Building Performance Rating System. *RESNET.* [Online] [Cited: January 26, 2009.] http://www.resnet.us/about/resnet.htm.

Each 1 percent increase in the energy efficiency of a home corresponds to a 1 point decrease in Index number.[9] Thus, the home described previously with an Index number of 60, is 40 percent more energy efficient than the home earning an Index number of 100.

On average, a home built before 2006 in the United States has an Index number of 130.[10] An average new home built after 2006 is represented by an Index number of 100.[11] RESNET defines an average new home as a home that meets the 2006 International Energy Conservation Codes (IECC). [12] Seventeen state governments have adopted the 2006 IECC as a state code. However, it should be noted that many states enforce less stringent codes, while other states, such as California and Oregon, enforce stricter energy efficiency codes. [13] On average, a newly constructed home is thirty percent more energy efficient than a home built before 2006.

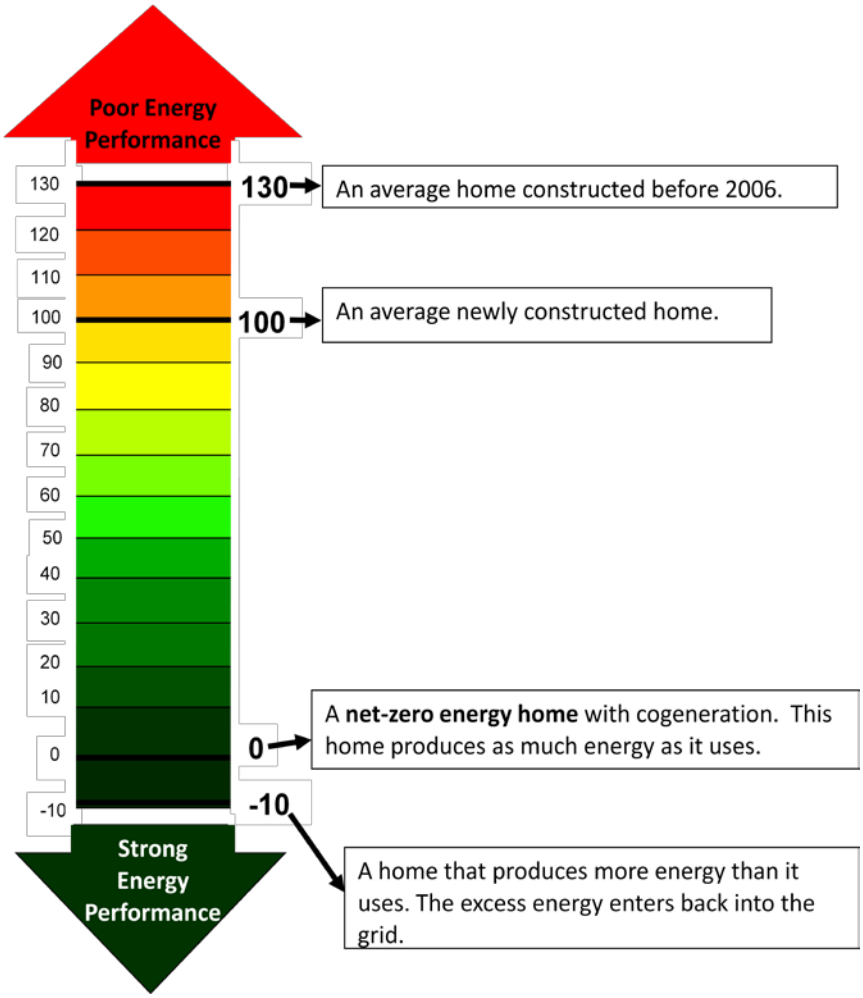

Figure 1: HERS Index Basics

A net-zero energy home with cogeneration earns an Index number of

[9] What's a HERS score. *Energy Star.* [Online] http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_HERS.
[10] About RESNET. *Residential Energy Services Network (RESNET).* [Online] http://www.natresnet.org
[11] ibid.
[12] ibid.
[13] State of the States Building Codes. *DOE.* [Online] http://www.energycodes.gov/implement/state_codes/state_status_full.php.

0.[14] This represents a home that produces as much energy as it uses after the addition of an on-site cogeneration system, such as photo voltaic panels.[15] Cogeneration can infinitely increase the energy efficiency of a home. A home that produces more energy than it consumes earns a negative Index number. Theoretically this excess energy produced would be sold back to the power grid.

Benchmarking Standards, Model Codes, Codes, and Guidelines Using the HERS Index

Benchmarking current standards, model codes, codes, and guidelines is useful for consumers, contractors, government agencies, and non-government organizations. Using HERS Index numbers allow parties to easily and quickly compare the effectiveness of all the different energy efficiency building tactics available. Quantifying popular energy efficiency programs and codes helps:

- **Consumers** understand the performance of their own residence and compare it with comparable homes. This information prompts homeowners to invest in energy efficiency improvements.
- **Contactors and developers** construct better performing buildings.
- **State and federal governments** ensure that the US Codes reflect the best technological advancements and practices.
- **Non-governmental organizations** compete with other non-governmental organizations to create the most advanced program regulations.

Presently, RESNET's HERS Index is calibrated according to the energy efficiency of the ICC's 2006 IECC.[16] As explained previously, the 2006 IECC has an Index number of 100. To determine the HERS Index number of other energy efficiency programs, one must compare the programs to the 2006 IECC. Because each 1 percent increase in energy efficiency corresponds to a 1 point decrease on the HERS Index, simply knowing the percentage a particular energy efficiency program is better or worse than the 2006 IECC, provides enough information to assign a program an Index number.[17]

If complying with a particular voluntary guideline improves the energy efficiency of a newly built home—which assumingly follows the 2006 IECC mandates—by 25%, then the guideline theoretically would create a home with an Index number of 75.

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[14] About RESNET.
[15] **Anderson, Ren.** *System Integration Research Leading to Zero Energy Homes.* s.l. : Building America, 2006.
[16] What's a HERS score. *Energy Star.* [Online] http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_HERS.
[17] What's a HERS score.

Determining HERS Index numbers can be complicated because energy efficiency programs are not always compared to the HERS Index or even the 2006 IECC. Often, programs are either compared to an average US home or to nothing at all. The lack of uniformity in state mandated codes also contributes to the complexity of quantifying energy efficiency programs. These obstacles only emphasize the need for establishing a precedent for using a common comparison metric such as the HERS Index.

Standards, Model Codes, Codes, and Guidelines

In order to comprehensively understand all the building energy efficiency programs in the United States, first it is necessary to clarify the difference between a standard, model code, code, and guideline.

Standards are developed by non-profit technical societies. These societies, such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and the National Association of Home Builders (NAHB), publish standards every three years based on their research. These standards theoretically represent the minimum allowable regulations that the building industry must follow to, as ASHRAE explains, "serve humanity and promote a sustainable world."[18] Standards organizations then petition model code organizations to adopt and enforce these standards.

Figure 2: How a standard becomes a model code.

A model code is a compiled set of regulations developed by an independent standards organization through a consensus process. A model code is a collection of building standards meant to protect homeowners and builders from out dated, dangerous, and poor building techniques.[19] Like standards organizations, model code organizations have no affiliation with federal or state governments. Rather, model code organizations are membership based associations. Professionals from the engineering, construction, and manufacturing fields review

[18] About Us. [Online] 2009. [Cited:] http://www.ashrae.org/aboutus/

[19] About ICC: Introduction to the ICC. *People Helping People Build a Safer World.* [Online] International Code Council, January 2009. http://www.iccsafe.org/news/about/.

submitted code proposals. [20] For a proposal to become a code it must first pass through a series of hearings and committee meetings. This open consensus process, which prevents interest groups from dominating standards' development, is graphically represented in Figure 2.

While a model code suggests how a home should be constructed, a code is a set of regulations adopted by a government that specifies how a building *must* be constructed. In the United States, a government body adopts a particular model code to enforce. Often a government will amend parts of a model code to best serve specific climatic and regional needs.[21] After adoption, the government body is also responsible for enforcing the code. In the United States, with the exception of manufactured housing, no federal residential building codes exist. Rather, each state or, in some cases, local government adopts specific model codes to enforce. [22, 23]

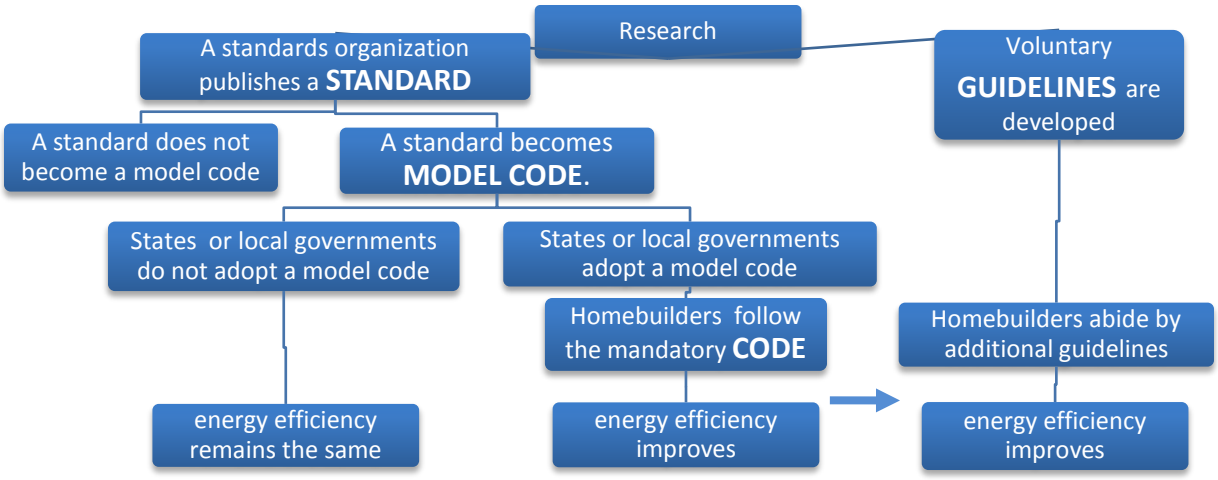

Figure 3: Relationship between a standard, model code, code, and guideline.

A guideline is a voluntary energy efficiency program established by either a governmental or non-governmental organization. Guidelines suggest additional building regulations homebuilders can follow in addition to the minimum practices specified by code. Guidelines promote the construction of more energy efficient homes by setting specific benchmarks, often accompanied by prestigious labels, for individual homeowners and builders to strive for. For instance, the US Green Building Council's LEED for Homes program has

[20] About ICC
[21] State of the States Building Codes.
[22] The HUD-Code. *Manufactured Housing Institute.* [Online] http://www.manufacturedhousing.org/lib/showtemp_detail.asp?id=78&cat=1.
[23] State of the States Building Codes.

prompted many homebuilders to construct green homes in order to receive public recognition and the "LEED certification" label.[24]

Standards

Organizations, such as ASHRAE and the National Association of Home Builders (NAHB), publish standards for residential buildings. NAHB recently published a green standard. The standard focuses on improving seven different building components:

1) Lot design, preparation and development
2) Resource efficiency
3) Energy efficiency
4) Water efficiency
5) Indoor environmental quality
6) Operation, maintenance, and homeowner education
7) Global impact

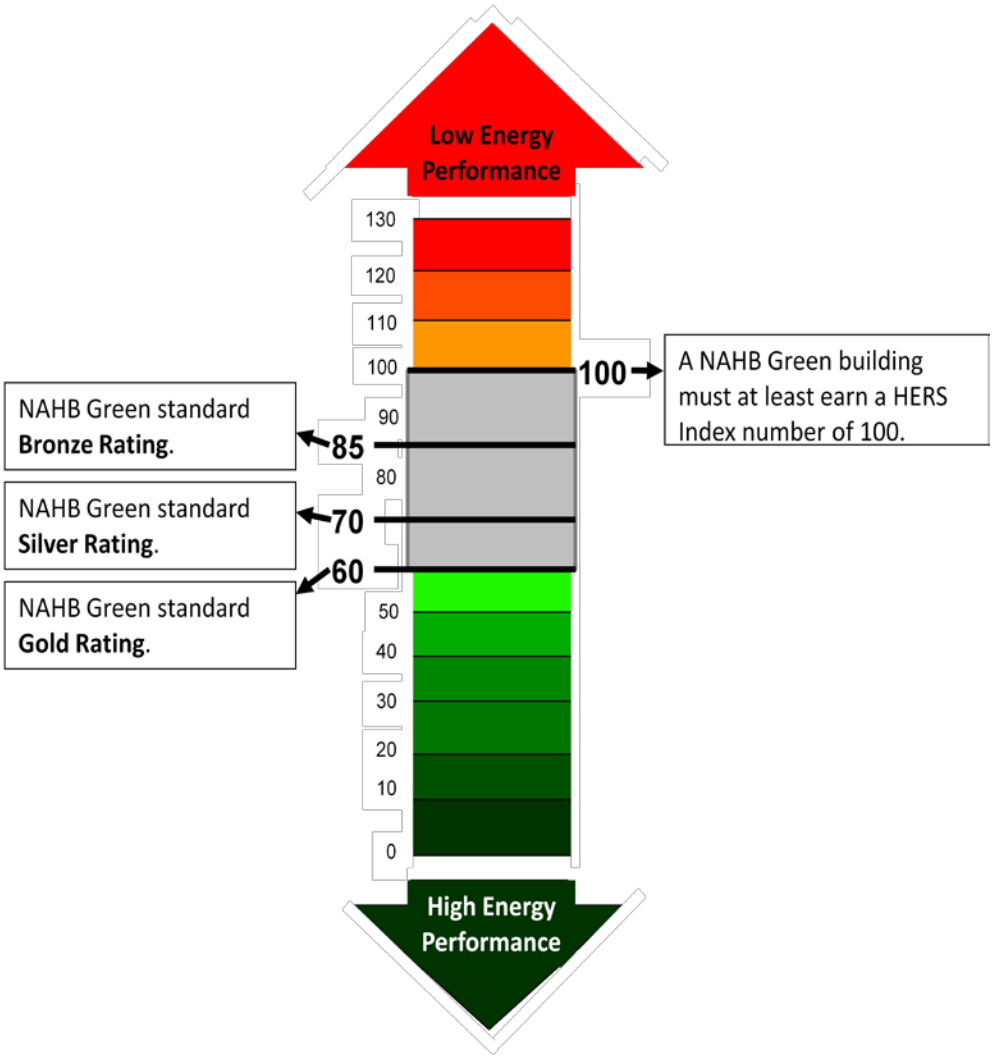

Figure 4: Standards.

The NAHB Green Standard encourages energy efficiency improvements through a point based system. At a minimum the NAHB Green Standard requires that homes follow the IECC or local code, whichever is more stringent. More points are earned if a home exceeds the IECC. A home fifteen percent better earns a bronze rating, thirty percent better earns a silver rating, and forty percent better earns a gold rating. Thus, homes that follow the NAHB Green Standard earn a HERS Index number between 60 and 100.[25]

[24] **Black, Sam.** LEED certification is here to stay. *Business Journal.* [Online] August 10, 2007. [Cited: January 2009, 2007.] http://www.bizjournals.com/twincities/stories/2007/08/13/focus1.html.
[25] NAHB Model Home Green Building Guidelines. 2006 http://www.nahbgreen.org/content/pdf/nahb_guidelines.pdf

Model Codes

The ICC publishes energy efficiency model codes. The ICC's most current published standard is the IECC 2006. A home built according to the IECC 2006 has an Index number of 100. The 2009 IECC has not yet been published. Several different organizations have begun predicting the difference between the 2006 IECC and 2009 IECC knowing that the 2009 IECC will require additional regulations such as duct sealing.[26] At the 2008 ICC Final Action Hearings, in September 2008, the DOE speculated that a home built according to the 2009 IECC will use 15 to 20 percent less energy than a home following the 2006 IECC.[27] However, four months later, the Energy Efficient Codes Coalition (EECC), predicted in the "ICF's Analysis of the Energy Savings achieved by the 2009 IECC" that the 2009 IECC will only decrease energy use in a home by 12.2 percent compared to the 2006 IECC.[28]

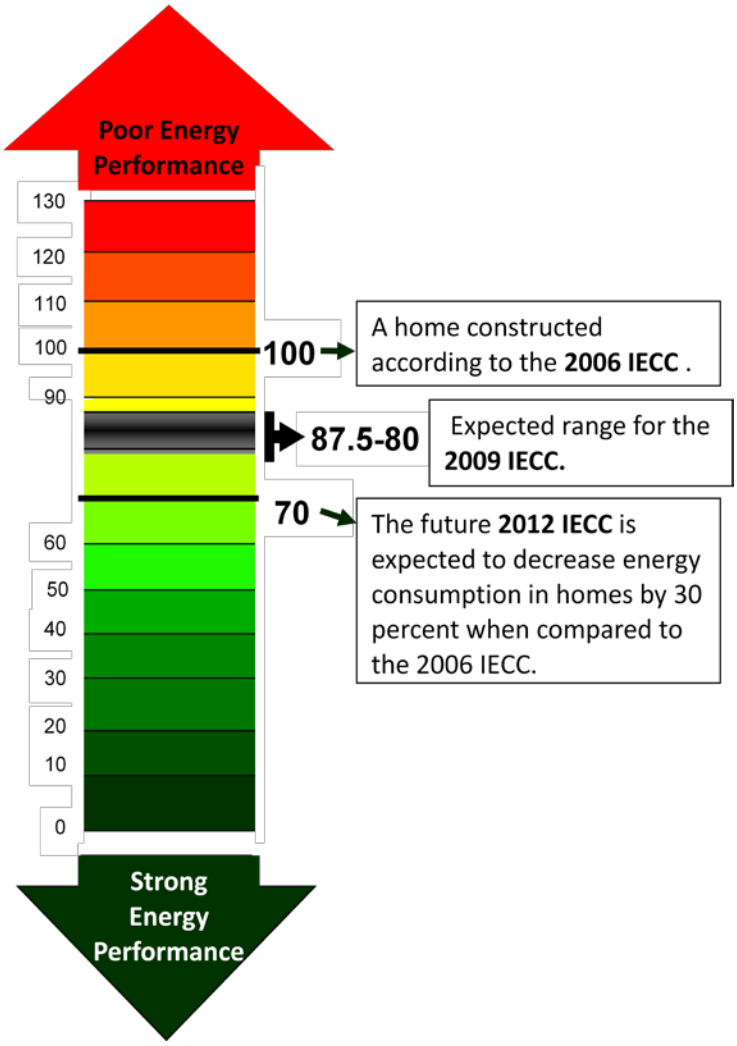

Figure 5: Model Codes.

[26] Program Highlights from August/September 2008. *DOE.* [Online] October 29, 2008. [Cited: January 6, 2009.] http://www.energycodes.gov/whatwedo/highlights.stm.
[27] Program Highlights from August/September 2008.
[28] ICF's Analysis of the Energy Savings achieved by the 2009 IECC. [Online] http://www.thirtypercentsolution.org/solution/ICF-data.pdf.

Codes

Federal Codes

A *Manufactured home*:
1) Is built in a factory.
2) Meets size specifications.
3) Remains on a permanent chassis.[33]

The Department of Housing and Urban Development regulates the energy efficiency requirements for manufactured housing through CFR 3280, known generally as the HUD-code. The HUD-code is the only federally regulated building code associated with residential building. Before 2005, HUD last revised and reviewed the energy efficiency regulations for manufactured housing in 1987 and published standards, the Manufactured Home Construction and Safety Standards (MHCSS), in 1992.[29] Although concrete data does not exist about the Index number for manufactured homes, the Index number is estimated to be above 100.[30]

Because of many advances in energy efficiency technology in the past decade, in 2005 HUD began revising the HUD-code by considering cost effective energy efficiency measures.[31] In compliance with the Energy and Security Act of 2007, Congress has required the HUD-code to be updated by 2011. The new 2011 HUD-code is expected to be equivalent to the 2009 IECC. However, the HUD-code will exclude all energy efficiency measures from the 2009 IECC that are deemed cost ineffective.[32] The energy efficiency of manufactured housing is therefore estimated to increase by about 15 to 20

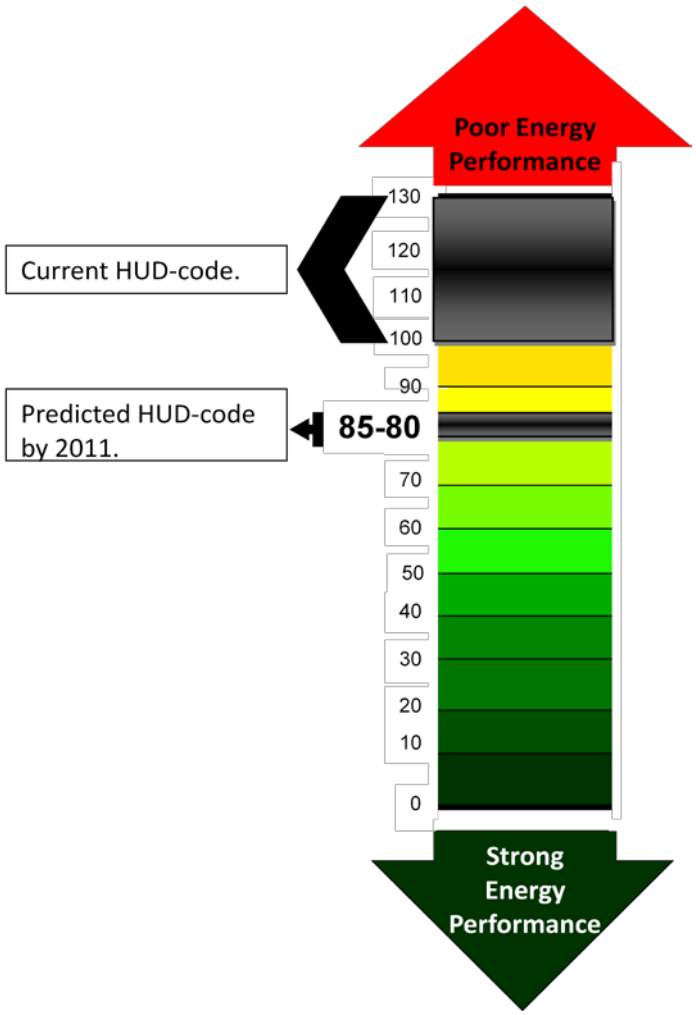

Figure 6: Federal Codes.

[29] **C.C. Conner, R.G. Lucas, H.E. Dillon, M. Lu**[illegible]gy-Efficiency Requirements in the Manufactured Home Construction and Safety Standards. *Pacific Northwest National Laboratory.* [Online] June 2004. http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14458.pdf.
[30] Chaser, Dave. "ICC and Manufactured Housing." E-mail to Joseph Hagerman. 23 Jan. 2009.
[31] **C.C. Conner, R.G. Lucas, H.E. Dillon, M. Lubliner.**
[32] US Department of Energy Beginning Development of Energy Efficiency Standards for Manufactured Housing. *DOE.* [Online] July 2008. [Cited:] http://www.energycodes.gov/codedevelop/mfg_hou

percent, earning an Index number between 80 and 85.[33]

State Codes

Without federal building codes, each state abides to separate regulations. As Figure 4 exemplifies, state codes range greatly in stringency. While California has recently adopted Title 24, which is estimated to be 30 percent more energy efficient than the 2006 IECC, the states of Illinois, South Dakota, Tennessee, and Wyoming have not adopted state-wide energy regulations.[34] It should be noted that in many cases local, city or county governments adopt and enforce energy codes.[35] This localized nature of building codes contributes to the difficulty in discerning the actual energy efficiency of specific states' buildings.

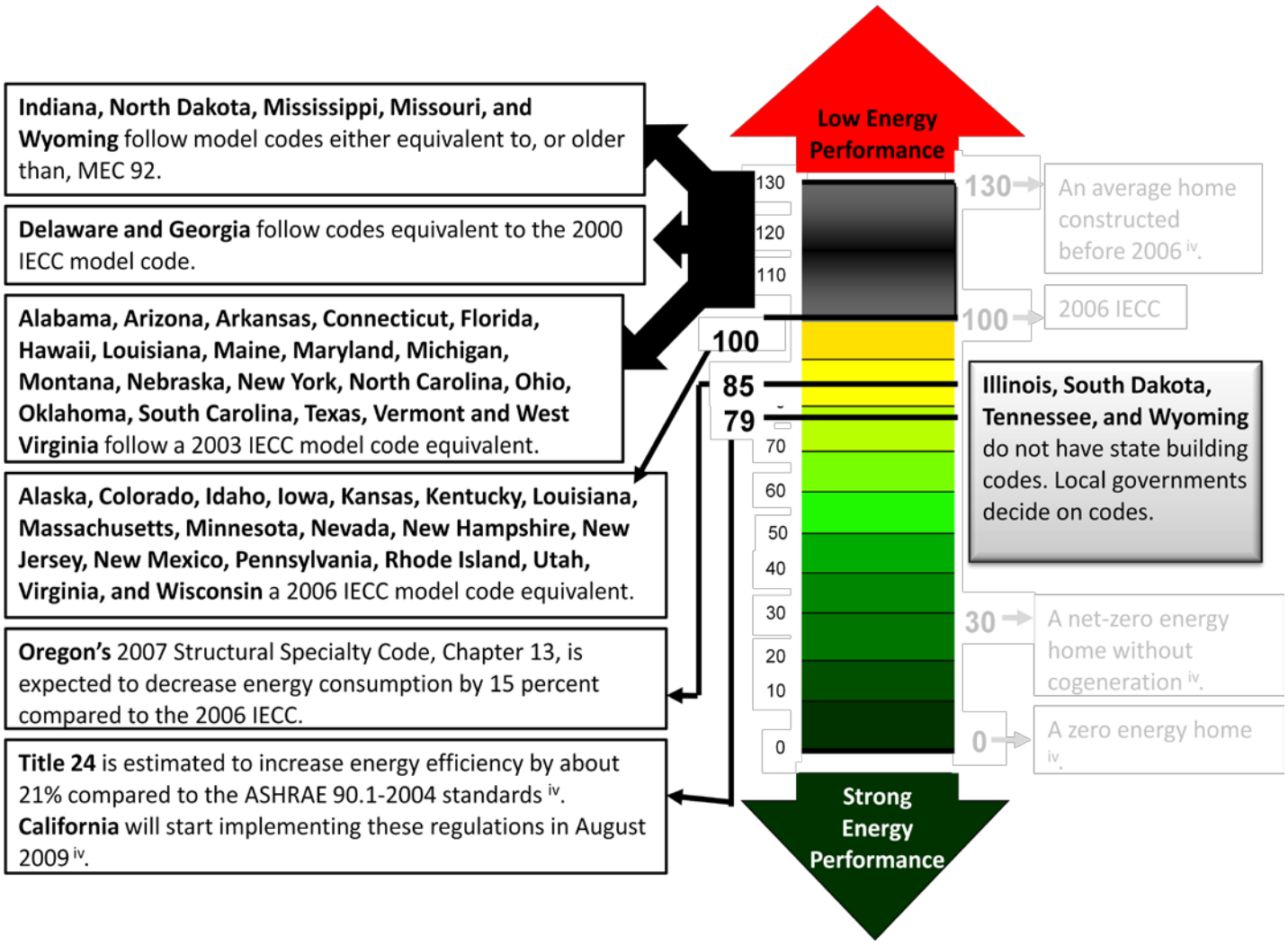

Figure 7: State Codes.

[33] The HUD-Code. *Manufactured Housing Institute.* [Online] http://www.manufacturedhousing.org/lib/showtemp_detail.asp?id=78&cat=1.
[34] Program Highlights from August/September 2008. *DOE.* [Online] October 29, 2008. [Cited: January 6, 2009.] http://www.energycodes.gov/whatwedo/highlights.stm.
[35] State of the States Building Codes.

Guidelines

The Department of Energy (DOE), the Environmental Protection Agency (EPA), and the US Green Building Council (USGBC) have all founded voluntary programs to promote the construction of energy efficient buildings. These programs are often followed, in addition to building codes, to increase the overall energy performance of a residence.

THE DEPARTMENT OF ENERGY

One of the DOE's longest building energy efficiency programs is the Building America program. By working with private organizations, DOE researches the best and most cost-effective energy efficiency techniques. Building America's latest objective is to reduce the energy use of all homes by 40 to 100 percent.[36] A home that fulfills the Building America goals therefore earns an Index number less than 60.

Another program from DOE is the Builders Challenge initiative.[37] The Builders Challenge encourages homeowners to decrease energy use by 30% to earn an Index number of 70.[38] The Builders Challenge promotes "the use of market-tested and cost-effective energy efficiency strategies" such as improved caulking and insulation. [39]

THE ENVIRONMENTAL PROTECTION AGENCY

Similar to the DOE's Builders Challenge, the EPA's Energy Star program promotes home energy efficiency improvements by replacing old appliances, caulking, windows and insulation.[40] The required Index number to be considered an Energy Star home depends on the location of the construction project. To qualify as an Energy Star building in the IECC's mild climate zones 1-5, as shown in Figure 6, a home must earn an Index

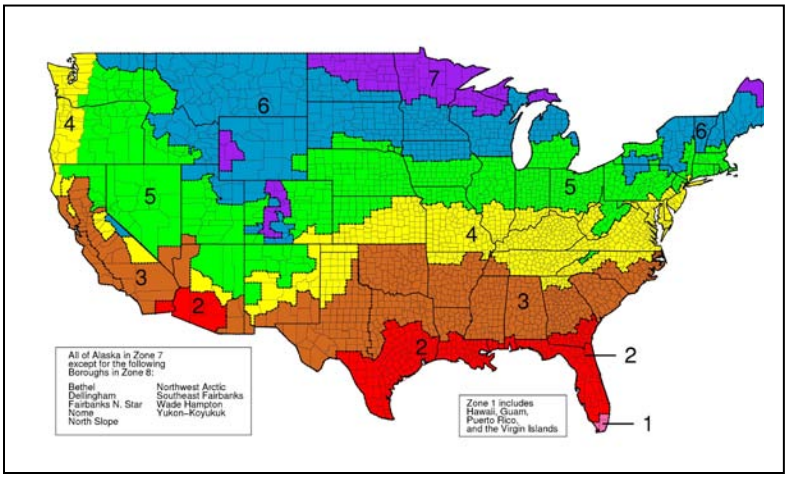

Figure 8: IECC Climate Zones. Used by DOE and USGBC.

[36] Building America. [Online] http://www1.eere.energy.gov/buildings/building_america/.
[37] Builders Challenge. *DOE.* [Online] May 20, 2008. [Cited: January 6, 2009.] from http://www1.eere.energy.gov/buildings/challenge/about.html.
[38] Builders Challenge.
[39] Builders Challenge--Recognizing Energy Leadership in Homebuilding. [Online] http://www1.eere.energy.gov/buildings/challenge/pdfs/bc_faqv3.pdf.
[40] What's a HERS score.

number of 85.[41] To qualify as an Energy Star building in the IECC cold climate zones 6-8, a home must earn an Index number of at least 80.

US GREEN BUILDING COUNCIL

Another popular energy efficiency initiative is the USGBC's Leadership in Energy and Environmental Design (LEED) for Homes program. The USGBC's program differs from other energy efficiency initiatives because certification is earned by following a set of prerequisites. The more prerequisites followed, the more points earned. LEED for homes considers several building components, including energy efficiency, water usage, and site orientation. [42]

A home at minimum needs a HERS Index number of 85 to be considered for LEED certification. Exceeding an Index number of 85 earns a home more LEED points, as displayed in Graph 1. A home with a HERS Index of 60 earns about 15.0 LEED points, while a home with a HERS Index of 0 (a zero energy home) earns 35.0 LEED points. [43] A 2008 study demonstrated that an average LEED certified home is 30 to 60 percent more energy efficient than an average home. [44]

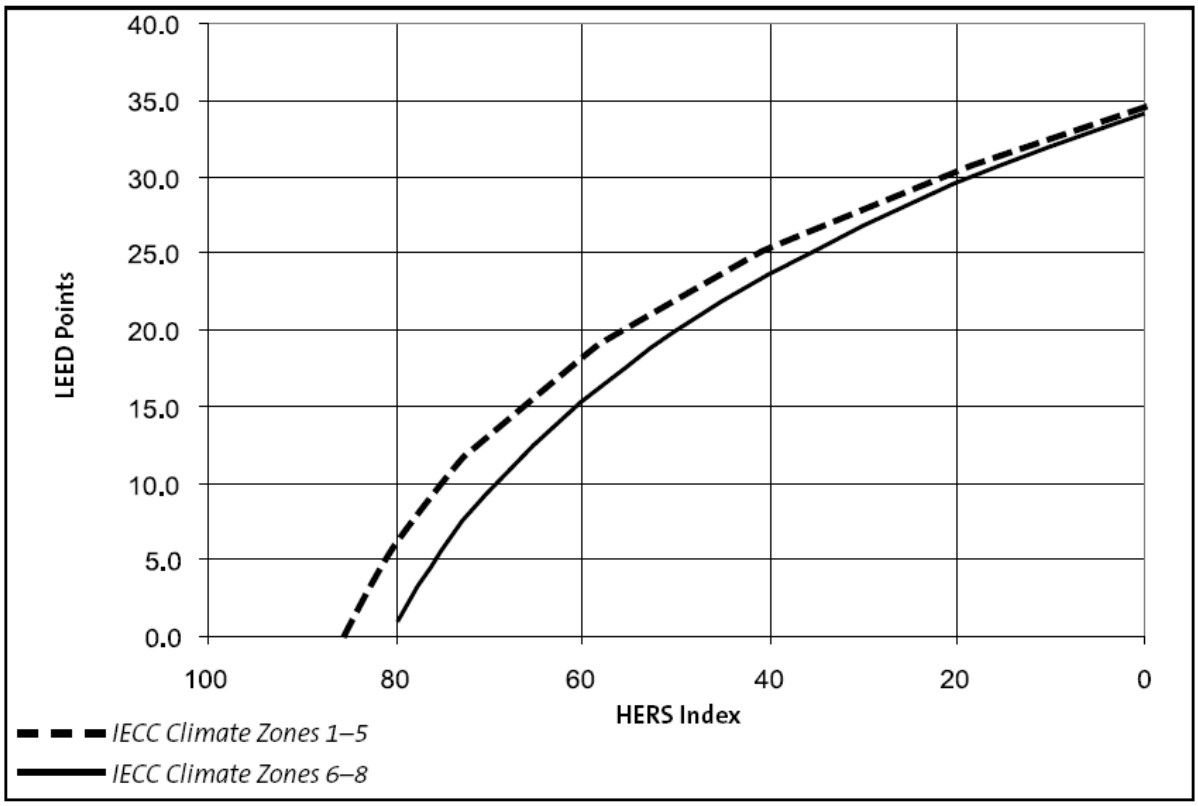

Figure 9: LEED Points vs. HERS Index Number. [43]

[41] What's a HERS score.
[42] LEED for Homes. *US Green Building Council.* [Online] http://www.usgbc.org/ShowFile.aspx?DocumentID=3936.
[43] LEED for Homes Rating System. January 2008. http://www.greenhomeguide.org/documents/leed_for_homes_rating_system.pdf
[44] Energy Performance of LEED for New Construction. http://www.usgbc.org/DisplayPage.aspx?CMSPageID=77.

ARCHITECTURE 2030

Architecture 2030 is an organization dedicated to decreasing the negative impacts of climate change by focusing on improving energy efficiency building codes. Architecture 2030 advocates for codes that by:

- 2010 are thirty percent below code (below IECC 2006).
- 2016 are fifty percent below code.
- 2022 are seventy five below code.
- 2028 are carbon neutral. [45]

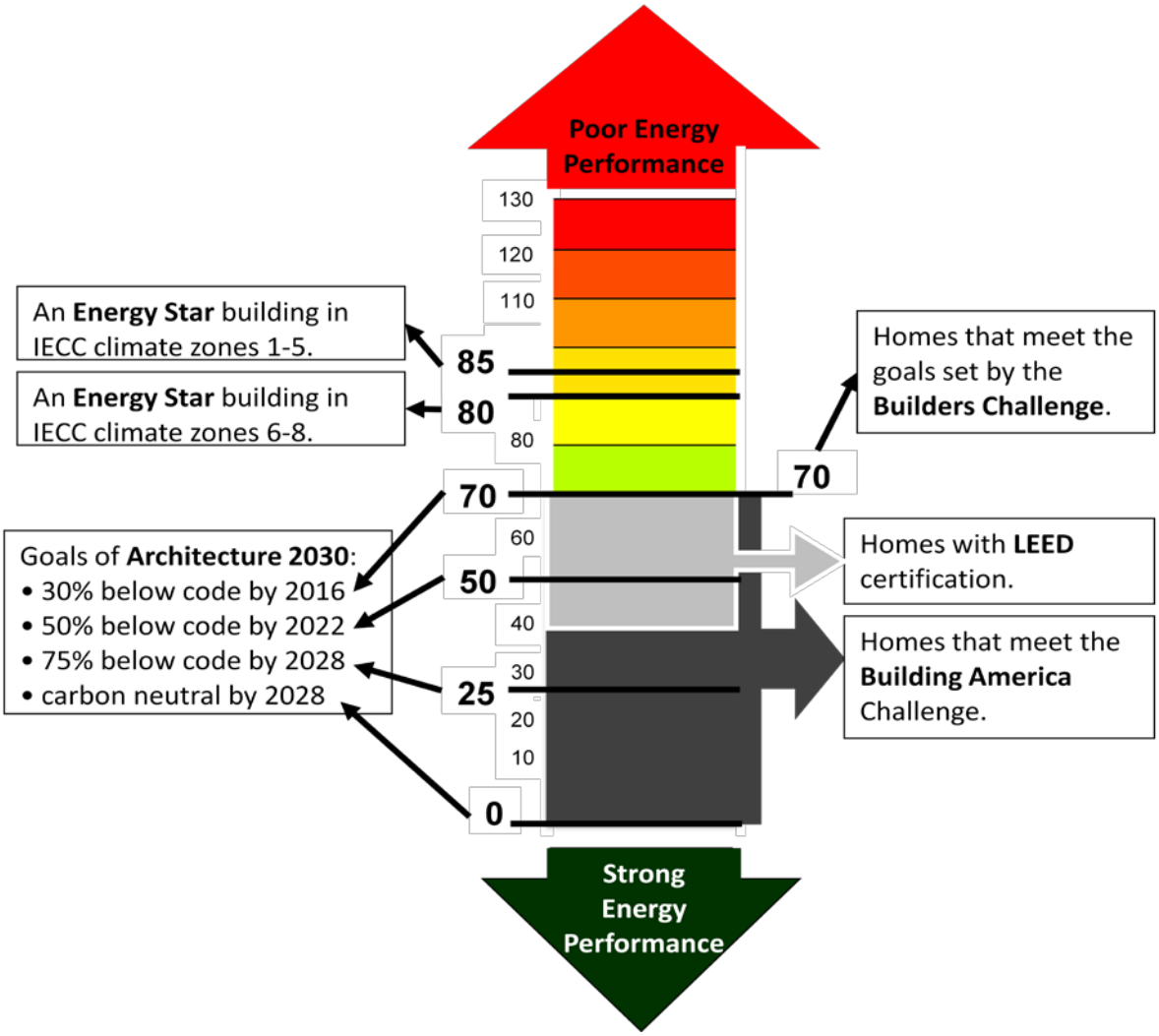

Figure 10: Summary of Popular Voluntary Guidelines and Initiatives

[45] Testimony of: Mr. Edward Mazria Founder and Executive Director 2030, Inc. / Architecture 2030. February 26, 2009. http://energy.senate.gov/public/_files/MazriaTestimony022609.pdf

Summary

A compilation of all the building model codes, codes, and guidelines is important for comparison purposes.

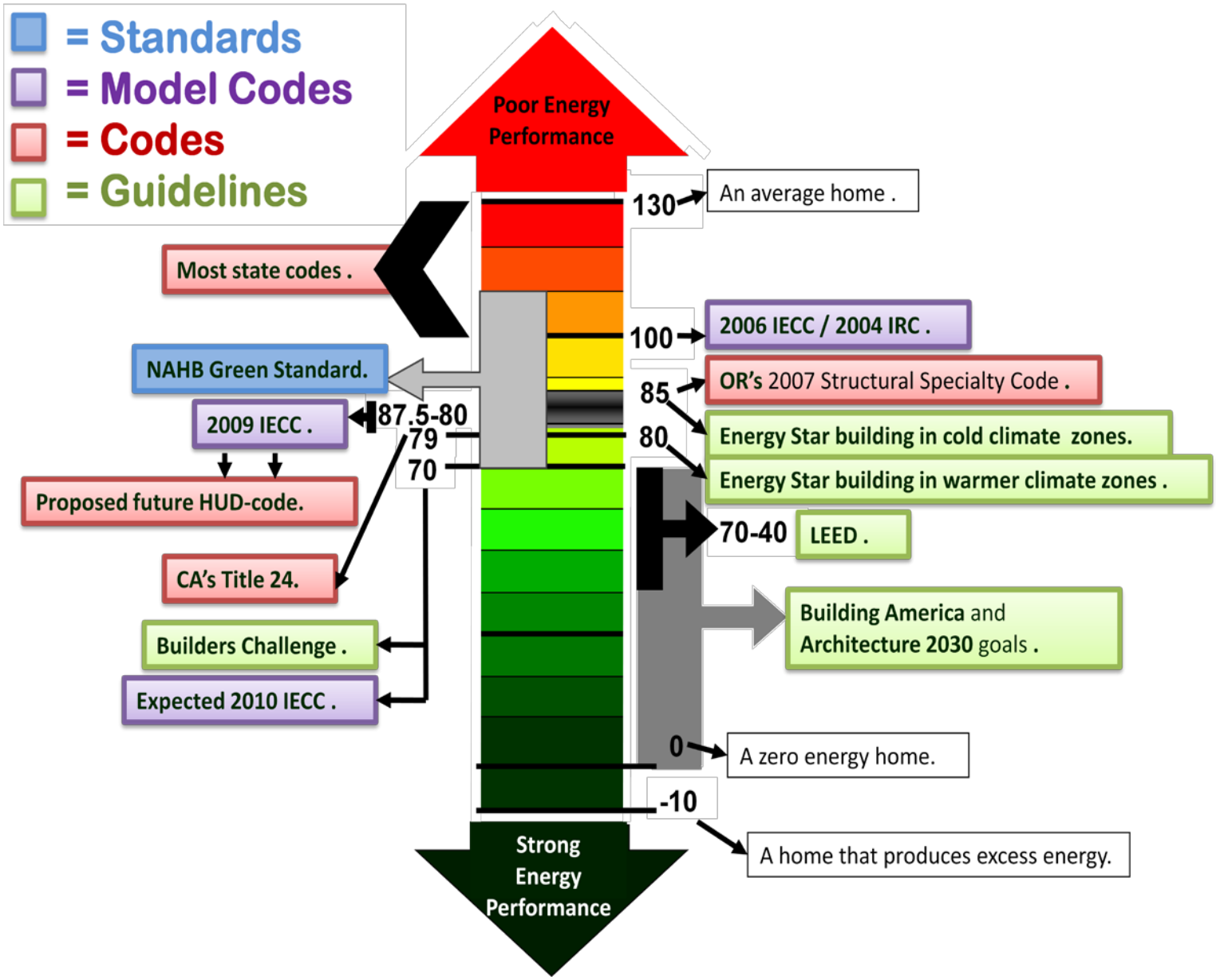

Figure 11: HERS Index with Model Codes, Codes, and Guidelines. Model codes are in purple, codes are in red, and guidelines are green.

Conclusions and Suggestions

START USING A COMMON METRIC TODAY

As this study on the HERS Index demonstrates, there currently exists a wide variety of standards, model codes, codes, and voluntary program relating to energy efficiency in the United States. With so many options for home owners and contractors, it is necessary that the use of a common metric becomes a norm in the building industry. Using a common metric will:

1) Help all parties understand the effectiveness of US energy efficiency programs and identify where further development is needed.
2) Allow homeowners, engineers, contactors, and architects find and follow optimal building efficiency programs during construction.
3) Encourage productive competition between organization and thus the creation of more progressive energy efficiency programs.
4) Promote the overall use of more sustainable building practices.
5) Help decrease the building industry's large contribution to green house gas production and climate change.

In the following centuries, the performance of new US building stock must, and will be forced to, improve significantly. The creation of new energy efficiency program is inevitable. To help solve national environmental, safety, and security problems and avoid unnecessary confusion, organizations must immediately start contributing and using a common comparison tool.

USE THE HERS INDEX

RESNET's HERS Index is a viable and useful metric tool ready to be used today. Some of the advantages of continuing to use the HERS Index are

1) No additional research and development, and therefore money, is needed.
2) The HERS Index is ready for immediate use by organizations.
3) Many, although not all, building organizations already compare and calibrate their own programs according to the HERS Index.
4) The metric has been used since the 1980s.[46]
5) The building industry and personnel who would use the HERS Index on a regular basis are already familiar with the tool.
6) Software to calculate a home's energy use is already developed.

[46] History of RESNET. http://www.resnet.us/about/history.htm.

BALANCE STATE AND FEDERAL RIGHTS TO CREATE OF OPTIMAL BUILDING PRACTICES

Although the lack of a federal residential building code adds greatly to the complexity of the US building system, it is vital to respect states' rights and sovereignty. Allowing each individual state to adopt separate energy code allows for the continual progression of safer and more stringent energy efficiency measures. If all states had to follow the same code, states, such as California and Oregon, would not be as progressive. It is imperative that these states take the lead in energy efficiency programs because it eases the future adoption of progressive energy codes in subsequent states.

At the same time, there needs to be minimum energy efficiency compliance across the board. To insure the safety and health of occupants, all states need to start adhering to the standards set by the 2006 IECC. Currently a variety of states, all with different climate, geographical and monetary priorities, have mandated the 2006 IECC. [47] From Nevada to Massachusetts to Louisiana, these states have shown that the adoption of a stringent energy efficient code is possible anywhere. Because buildings are the greatest contributor to green house gases in the US, steps need to be taken to instate mandatory minimum energy codes.

[47] State of the States' Energy Code.

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