NEWPORT VENTURES

Improving Thermal Performance of Single Family Homes in Hawaii through High Solar Reflectance Coatings on Above Grade Walls

Overview

Hawaii has a unique, cooling-dominated climate that is shared with less than half of one percent of the total U.S. land area. The International Energy Conservation Code (IECC) refers to this climate as "climate zone 1" (CZ 1). With virtually zero heating load and cooling degree days that can be 2-3 times greater than those in moderate mainland U.S. climates (e.g. climate zones 3–4), Hawaii's unique climate deserves special consideration when adopting the 2009 IECC. By adopting climate-appropriate amendments, Hawaii can ensure that its energy code measures are both aggressive and effective – from an economics and environmental position.

Hawaii is also different from most other parts of the United States because of the presence of the Formosan termite. Since the 1990s, a large percentage of homes built in Hawaii have been constructed from steel framing specifically to prevent losses from this aggressive termite. In the effort to establish equivalent thermal performance across all types of above grade walls, the IECC has imposed strict continuous insulation requirements on steel-framed homes, without regard to the additional benefits that can be realized by steel framing (e.g. termite resistance), and without providing alternative prescriptive options for achieving equivalent energy savings. Fortunately, building energy simulations show there are methods other than the use of continuous insulation that can be used in Hawaii to achieve equivalent thermal performance at much lower cost to the homeowner.

This document reviews the effectiveness of a Hawaii-specific proposed amendment to the 2009 IECC which would permit a trade-off for continuous insulation that would otherwise be required for steel-frame assemblies. Traditionally, trade-offs to requirements in energy codes are structured to provide:

- Equivalent thermal performance
- Increased options for builders and designers
- Removal of discrimination between materials and barriers to market-entry of innovative products
- Opportunity for reduced costs for consumers

The trade-off analyzed within this document was the specification of wall coverings with a solar reflectance (SR) of 0.45. Recently, Oak Ridge National Laboratory conducted a study that showed that reflective paints can save up to 4%-13% of the cooling energy used in homes, with highest savings possible in warmer climates.[1] Based on this and other claims of thermal performance benefits of coverings with

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[1] Petrie, T.W., J.A. Atchley, et. al. 2007. Energy savings for stucco walls coated with cool colors. Proceedings of the Thermal Performance of the Exterior Envelopes of Whole Building X, Florida, USA. December. http://www.ornl.gov/sci/roofs+walls/staff/papers/20.pdf.

high SR values, Newport conducted a study for the Steel Framing Alliance that sought to quantify the benefit of coverings with high SR values when used over steel-framed walls without continuous insulation.

The study used building energy simulation models to compare the thermal performance benefits of above grade wall coverings with SR=0.45 versus above grade walls using R-5 continuous insulation. The following sections detail the building energy simulation results that show that equivalent thermal performance can be achieved with this trade-off.

Building Energy Simulation Models

Simulations were conducted using Energy Gauge USA 2.8.04. Energy Gauge software is accredited by the Residential Energy Services Network (RESNET), and is approved for demonstrating compliance with Chapter 4, Section 405 of the 2009 IECC. Energy Gauge was developed by Florida Solar Energy Center, so it is a program that was formulated with hot, tropical climates in mind. Further, it uses the Department of Energy's "DOE 2.1E" building energy simulation engine to produce hourly calculations, which are typically preferred to seasonal calculations used by other IECC compliance simulation programs.

A typical, 2400 sqft, three bedroom, single family, two story home with steel-framed walls was modeled at four locations across Hawaii: Hilo, Honolulu, Kahului, and Lihue. A list of all assumptions is given in Table A1 of the Appendix. For each location, a simulation was run with the reference home modeled according to the guidelines of Table 405.5.2(1) where options were given for user inputs within the software, with the exception of R-13+5, 16" o.c. steel framed walls (prescriptive requirement of Table 402.2.5, REScheck[2]-sourced U-factor of U-0.077). Cooling energy use was recorded, and then simulations were run again with steel-framed walls that use R-13 cavity insulation plus a wall covering with a solar absorptance of 0.55. For the purposes of this simulation, this value of solar absorptance was assumed to correspond to a solar reflectance 0.45. The relationship between solar absorptance (SA) and solar reflectance (SR) was computed as:

$$SA=1-SR$$

This calculation lead to slightly conservative values of solar absorptance (i.e. higher values of solar absorptance) than would otherwise be calculated if solar transmittance were considered in this equation. So, based on this conservative assumption, simulated savings associated with high solar reflectance coverings should be slightly underestimated. For both the reference home and the home with walls of high solar reflectance, the wall emissivity was held constant at 0.9, as defined in IECC Table 405.5.2(1).

Results

By considering the total cooling energy use across the four locations, results showed that, on average, thermal equivalence can be achieved by trading-off a covering with SR=0.45 for R-5 continuous insulation on a 16" o.c. steel-framed wall with R-13 in the cavity. Table 1 contains the results from the study.

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[2] REScheck is a software program developed by the U.S. Department of Energy for the purpose of demonstrating compliance with energy codes.

Steel-frame Analysis	**Honolulu**	**Hilo**	**Kahului**	**Lihue**	**Average Savings**
Cooling energy (kWh), R-13+5, 16" o.c. steel-framed walls, SR=0.25, 2009 IECC Prescriptive Minimum	5302	2619	4339	4300	N/A
Cooling energy (kWh), 16” o.c. steel-framed walls, SR=0.45	5313	2592	4345	4288	5.5

Table 1. Study results showing slightly lower cooling energy use for single family detached homes with above grade walls with coverings of SR=0.45 than for homes with walls with R-5 continuous insulation.

In addition to providing simulated thermal equivalence, coverings with SR≥0.45 are likely to be more affordable to consumers than R-5 continuous insulation. Installed cost of the continuous insulation was assumed to be $1.52/sqft for R-5. This estimate was developed by using 2010 RS Means Residential Cost Data for 1” R-5 extruded polystyrene or in Honolulu and applying a 20% builder mark-up. The ~2400 sqft home modeled had 2534 sqft of gross wall area, for a total installed cost to the homebuyer of $3,863 for the R-5 continuous.

In contrast, paint coverings with SR≥0.45 are expected to have a minimal incremental cost to consumers – on the order of a few hundred dollars per home versus a few thousand dollars. This rough estimate is based on inquiries with manufacturers of the product. Regardless of the final cost, the measure is expected to be much less expensive than continuous insulation, and the proposal does not require that products with this performance level be used, so consumers and designers would simply have the option of specifying high reflectance coverings. At this time, there are only a few suppliers of paints with published solar reflectance values. However, placing this trade-off in the code should trigger product innovation and increase the availability of new products on the market that can meet this performance specification.

Proposed Hawaii-Specific Amendment to the 2009 IECC

The trade-off proposed within this document is the use of a covering for above grade steel-framed walls that has a solar reflectance value of 0.45 or greater in exchange for the R-5 continuous insulation requirement for steel-framed walls contained within the 2009 IECC. The proposed change to the 2009 IECC that would incorporate this trade-off is as follows:

402.2.5 Steel-frame ceilings, walls, and floors. Steel-frame ceilings, walls and floors shall meet the insulation requirements of Table 402.2.5 or shall meet the U-factor requirements in Table 402.1.3. The calculation of the U-factor for a steel-frame envelope assembly shall use a series parallel path calculation method.

Exceptions: ~~In Climate Zones 1 and 2,~~ T~~t~~he continuous insulation requirements in Table 402.2.4 shall be permitted to be reduced to:

1. R-3 for steel frame wall assemblies with studs spaced at 24 inches (610 mm) on center.
2. R-0 for steel frame wall assemblies that have an exterior paint or surface with a solar reflectance of 0.45 or greater.

This proposed change is supported as an equivalent trade-off for Chapter 4 of the 2009 IECC by building energy simulations under the assumptions outlined within the Appendix.

Appendix

Table A1. Housing and Location Characteristics, Single Family Detached Reference Home

Location	Hawaii, multiple
House orientation for front of home	SE
Above grade sqft	2434
Aspect ratio	1.3
Length (ft)	39.8
Width (ft)	30.6
First Floor Ceiling Height (ft)	9.0
Second Floor Ceiling Height (ft)	8.0
Conditioned area (sqft)	2434
Conditioned volume (cuft)	20689
Housing Type	SFD
# Stories (floors on or above grade)	2
Number of bedrooms	3
Conditioned floors (including basement where applicable)	2
Foundation	
Slab on grade (Yes=1, No=0)	1
Slab on grade area (sqft)	1217
Foundation Full Perimeter (ft)	141
Band Joist	
Band joist area (sqft)	141
Cavity insulation R-value (Assumed grade I)	13
Cavity insulation thickness (in)	3.5
Above Grade Wall	
Solar absorptance (as per IECC 2009 Table 405.5.2(1)	0.75
Remittance, aka emissivity (as per IECC 2009 Table 405.5.2(1))	0.9
Calculation of solar absorptance (SA) for improved home based on solar reflectance (SR), leading to conservative (higher) values for SA than if solar transmittance (ST) were also considered (e.g. SA=1-SR-ST)	SA=1-SR
Stud depth and insulation depth (in)	3.5
Stud spacing (in o.c.)	16"
Cavity insulation R-value (Assumed grade I)	13
Gross area (sqft)	2533
Northwest (sqft)	716
Southeast (sqft)	716
Northeast (sqft)	551
Southwest (sqft)	551
Windows	
U-value	1.2
Solar Heat Gain Coefficient (SHGC)	0.3
Gross area (sqft)	380
Northwest (sqft)	126
Southeast (sqft)	126
Northeast (sqft)	64
Southwest (sqft)	64
Interior shading, winter, IECC default	0.85

Interior shading, summer, IECC default	0.70
Doors	
U-factor	1.2
Gross area (sqft)	40
Attic/Ceiling	
Gross area (sqft)	1217
Total insulation R-value (Assumed grade I)	30
Bottom chord/rafter spacing (in oc)	24
Bottom chord/rafter size, wxh (in)	1.5x3.5
Mechanical Equipment	
Location of all mech equipment	Attic
Cooling set point (deg F)	75
Air conditioner, minimum federal SEER rating	13 SEER
Water heating, electric tank	40 gal, 0.92 EF
Duct insulation R-value (100% in attic)	8
Duct leakage to outside (cfm/100 ft2)	0.08
Infiltration (IECC default SLA)	0.00036

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