



ANALYSES AND PROPOSAL OF HAWAII AMENDMENTS TO THE 2015 INTERNATIONAL ENERGY CONSERVATION CODE

Prepared for the
Department of Business, Economic Development, and Tourism
State of Hawaii



May 2016

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This material is based upon work supported by the Department of Energy under Award Number DE-EE0003928/0014.

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Abstract

Hawaii attracted national attention by announcing that 100% of its electrical power will be derived from renewable sources by 2045. Achieving this goal requires lowering electrical consumption and increasing renewable power generation until the lines meet.

Homes and buildings account for most of Hawaii's electrical use, and robust building energy codes are an extremely effective means of shrinking that usage.

The Hawaii Building Code Council adopted the 2015 International Energy Conservation Code (IECC) on July 14, 2015, paving the way for adoption by Administrative Rule and county. Homes and buildings built to the 2105 IECC use about 30% less energy than those built to the 2006 IECC—Hawaii's prior code. Hawaii's amendments reduce energy use by up to another 3%.

This Analysis describes the methodology employed in assessing the effectiveness of each efficiency measure and describes the steps needed to meet federal requirements regarding energy code legislation. A twenty-year savings forecast is provided to demonstrate the potential energy savings for adoption and compliance of the 2015 IECC for residential and commercial buildings.

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LIST OF ACRONYMS

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
Auto-DR	automated demand response
BC3	Building Component Cost Community
CNMI	Commonwealth of the Northern Mariana Islands
DOE	U.S. Department of Energy
DX	Direct Expansion
EEPS	Energy Efficiency Portfolio Standard
EUI	energy use intensity
FERC	Federal Energy Regulatory Commission
Fiji	Republic of the Fiji Islands
HAR	Hawaii Administrative Rules
HEC	Hawaii Energy Code
HRS	Hawaii Revised Statutes
HSEO	Hawaii State Energy Office
HVAC	heating, ventilation and air-conditioning
ICC	International Code Council
IECC	International Energy Conservation Code
IgCC	International Green Construction Code
IRC	International Residential Code
kWh	kilowatt-hour
MW	megawatts
PF	projection factor
SA	solar absorptance
SBCC	State Building Code Council
SEER	Seasonal Energy Efficiency Ratio
SHGC	solar heat gain coefficient

SR	solar reflectance
U.S.	United States
VAV	variable air volume
WFR	window-to-floor ratio
WPF	Wall projection factor

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1 EXECUTIVE SUMMARY

Hawaii imports the majority of energy used throughout the state and, as a result, customers are experiencing the highest electricity prices in the nation. Approximately twenty-five percent of energy use statewide can be attributed to buildings. This provides an opportunity to reduce energy consumption through increased efficiencies.

Hawaii's current energy code, the 2006 Hawaii Energy Code (HEC), is based on the 2006 International Energy Conservation Code (IECC) with state-specific amendments. The IECC has been updated twice since its inclusion in the HEC; the most recent version available is the 2015 IECC. Each time the IECC and ANSI/ASHRAE/IES Standard 90.1 are updated, the United States Department of Energy is required by statute to issue a determination as to whether the updated edition will improve energy efficiency in buildings over previous versions of the code or standard. Upon publication of an affirmative determination, states are required to certify that they have reviewed the provisions of the commercial and residential building codes regarding energy efficiency and, as necessary, update their codes to meet or exceed the most recent editions.

Building on previously approved amendments from the State Building Code Council, the Hawaii State Energy Office has contracted with the Consultant to provide analyses of proposed amendments to residential and commercial provisions of the 2015 IECC. The outcome of this analysis will be to achieve adoption at the state and county level. In addition, the Hawaii State Energy Office will demonstrate to the United States Department of Energy that the adopted HEC meets or exceeds the efficiency levels of the 2015 IECC and ANSI/ASHRAE/IES Standard 90.1-2013.

Due in part to the increased stringency of the 2015 IECC and the inclusion of Section R401.2.1, Tropical Zone, Hawaii has to make fewer modifications to the IECC than in previous years. The greatest energy savings in the residential sector will be due to decreasing cooling loads, increasing comfort with natural ventilation, and eliminating electric water heating. Among the cooling permutations analyzed, the most efficient were semi-conditioned, or mixed-mode, residential units. They were 9-13% more efficient than the base 2015 IECC residences and would be even more efficient with appropriate air sealing between conditioned and un-conditioned spaces. The most efficient homes were naturally ventilated, which eliminated cooling equipment entirely, while designed to take advantage of cooling breezes and eliminate solar heat gain.

The permutations ran on fully conditioned 2015 IECC residences resulted in -1 to 3% improvements in efficiencies (see Table 10). As a result, a point system is recommended to ensure that conditioned homes are "energy neutral" when compared to the semi-conditioned units. The point system will also accommodate the tradeoffs established by the State Building Code Council. Within the commercial sector, the most significant efficiencies will be due to sub-metering, automated demand response and in-room energy management systems.

The net overall impact of the 2015 IECC with Hawaii amendments is estimated to be a savings of 12,962 MWh in 2016; 1,083,590 MWh in 2026 (year 10); 1,991,059 MWh in 2030; and 4,702,738 MWh in 2036 (year 20).

2 SUMMARY OF RECOMMENDATIONS

The Consultant recommends the following amendments to the 2015 International Energy Conservation Code (IECC).

2.1 COMMERCIAL

1. **Scope and Administration Amendments.** The title of the energy code as well as requirements for construction documents shall be amended to reflect standard code language and practice in Hawaii. Refer to Section 6.1.1.
2. **Low-Energy Use Buildings.** Low energy buildings that are not required to comply with the building envelope requirements of the code shall be amended to include unconditioned space that does not contain habitable space. Refer to Section 6.1.2.
3. **Wall Insulation.** Exceptions and alternatives for continuous wall insulation will be permitted depending upon the assembly type and exterior shading in accordance with Section 6.1.2.2.
4. **Area-weighted SHGC.** An area-weighted average of fenestration products shall be permitted to satisfy SHGC requirements. Refer to Section 6.1.2.3.
5. **In-Room Energy Management Systems/Door Switches.** Opaque and glass doors opening to the outdoors in hotel and motel sleeping units, guest suites and time-share condominiums, shall be provided with controls that disable the mechanical cooling, or reset the cooling setpoint to 90° F or greater within five minutes of the door opening. Mechanical cooling may remain enabled if the outdoor air temperature is below the space temperature. Refer to Section 6.1.2.4.
6. **Specific Application Controls.** Time-share condominiums shall have a master control device that is capable of automatically switching off all installed luminaires and switched receptacles within 20 minutes after all occupants leave the room. Refer to Section 6.1.2.5.
7. **Sub-Metering.** In new buildings with tenants, metering shall be collected for the entire building and individually for each tenant occupying 1,000 ft² (total enclosed and unenclosed) (93 m²) or more. Tenants shall have access to all data collected for their space. A tenant is defined as “one who rents or leases from a landlord.” Refer to Section 6.1.2.6.
8. **Automated Demand Response.** As deemed feasible by Hawaiian Electric Company and/or Kauai Island Utility Cooperative, amend the 2015 IECC to include applicable sections of the International Green Construction Code (IgCC) Section 604, Automated Demand Response Infrastructure. Refer to Section 6.1.2.7.
9. **Existing Building Amendments.** Requirements for existing buildings shall be amended to be consistent with current Hawaii statutes, including striking language requiring existing building projects to comply with the suite of International Codes. Proposed amendments also ensure that uninsulated roofs for existing buildings will meet the requirements of the IECC as part of a roof replacement. Refer to Section 6.1.3.

2.2 RESIDENTIAL

2.2.1 Scope and Administration Amendments

Requirements for construction documents shall be amended to reflect standard code language and practice in Hawaii. Refer to Section 6.2.1.

2.2.2 All Homes

1. **Project Compliance.** Projects must comply with one of the options listed in Section R401.2, which shall be amended to specifically reference Tropical. Zone requirements as an option. Refer to Section 6.2.1.2.
2. **Low-Energy Use Buildings.** Low energy buildings that are not required to comply with the building envelope requirements of the code shall be amended to ensure that habitable space, even if unconditioned, will be covered by the provisions of the energy code. Refer to Section 6.2.1.3.
3. **Wall Insulation.** The Points-Based Option will allow trade-offs for continuous wall insulation. Refer to Section 6.2.2.1.
4. **Ceiling Fans.** All bedrooms and the largest space that is not used as bedroom must have a ceiling fan or ceiling fan rough-in. Refer to Section 6.2.2.2.
5. **Domestic Water Heating.** Solar water heating systems shall be required for new single-family residential construction. Refer to Section 6.2.2.3.
6. **Roof Ventilation.** See Points-Based Option. Refer to Section 6.2.4.1.
7. **Roof Insulation.** See Points-Based Option. Refer to Section 6.2.4.2.
8. **Fenestration Shading Options.** Fenestration products must meet the requirements of Table R402.2.1, Window Solar Heat Gain Coefficient Requirements. Refer to Section 6.2.3.1.

Table R402.2.1. Window Solar Heat Gain Coefficient Requirements

Projection Factor of overhang from base of average window sill ^b	Solar Heat Gain Coefficient
< .30	.25
.30 - .50	.40
≥.50	N/A

^bException: North-facing windows with pf > .20 are exempt from the SHGC requirement.
Overhangs shall extend 2 feet on each side of window or to nearest wall, whichever is less.

9. **Points-Based Option for Prescriptive Approach.** An energy neutral points-based option is proposed for the Prescriptive Approach (Section R402.1). The points-based option builds on the steel framed wall exceptions currently allowed in the 2006 HEC and provides increased flexibility for the prescriptive approach by allowing trade-offs for reduction in steel frame wall insulation and reduced roof insulation.

The goal of the points-based option is to score a “0” or greater for the wall and roof assembly types. Each of the options indicated in Table 11 is worth approximately 1% energy increase or decrease and is based on the analysis performed for other options discussed in Section 6.0. Refer to Section 6.2.4.

2.2.3 ≤ 50% Cooled Homes (Tropical Homes)

1. **Domestic Water Heating.** A solar energy source must supply not less than 90 percent (90%) of the energy for service water heating. Refer to Section 6.2.2.3.
2. **Fenestration Shading Options.** Fenestration products must meet the requirements of Table 9, Window Solar Heat Gain Coefficient Requirements. Refer to Section 6.2.3.1.
3. **Roof and Ceiling Requirements.** The roof/ceiling must comply with one of the following options:

1. Comply with one of the roof surface options in Table C402.3 and install R-13 insulation or greater.
2. Install R-19 insulation or greater.

If present, attics above the insulation are vented and attics below the insulation are unvented.

Exception: The roof/ceiling assembly are permitted to comply with Section R407.

Refer to Section 6.2.4.

4. **Air Leakage Allowance.** Apply Hawaii’s 2009 amendment for 1.2 cfm/ft² air leakage allowance of jalousie windows to Section R402.4.3. Refer to Section 6.2.3.3.
5. **Envelope Requirements.** Apply all roof and wall assembly provisions of the IECC to multi-mode and naturally ventilated homes. Refer to Section 6.2.3.1.
6. **Points-Based Option for Prescriptive Approach.** An energy neutral points-based option is proposed for the Prescriptive Approach (Section R402.1), as described above. Point options are fewer for naturally ventilated homes as the Tropical Zone already requires certain cooling related features. Each of the options indicated in Table 11 is worth approximately 1% energy increase or decrease and is based on the analysis performed for other options discussed in Section 6.0. Refer to Section 6.2.4.

Table 11. Proposed Points Options

<u>Walls</u>		<u>Standard Home Points</u>	<u>Tropical Home Points</u>
Wood Framed			
	<u>R-13 Cavity Wall Insulation</u>	<u>0</u>	<u>1</u>
	<u>R-19 Roof Insulation</u>	<u>-1</u>	<u>0</u>
	<u>R-19 Roof Insulation + Cool roof membrane¹ or Radiant Barrier³</u>	<u>0</u>	<u>1</u>
	<u>R-19 Roof Insulation + Attic Venting²</u>	<u>0</u>	<u>1</u>

	<u>R-30 Roof Insulation</u>	<u>0</u>	<u>1</u>
	<u>R-13 Wall Insulation + high reflectance walls⁴</u>	<u>1</u>	<u>2</u>
	<u>R-13 Wall insulation + 90% high efficacy lighting and Energy Star Appliances⁵</u>	<u>1</u>	<u>2</u>
	<u>R-13 Wall Insulation + exterior shading wpf=0.3⁶</u>	<u>1</u>	<u>2</u>
	<u>Ductless Air Conditioner⁷</u>	<u>1</u>	<u>1</u>
	<u>1.071 X Federal Minimum SEER for Air Conditioner</u>	<u>1</u>	<u>1</u>
	<u>1.142 X Federal Minimum SEER for Air Conditioner</u>	<u>2</u>	<u>2</u>
	<u>No air conditioning installed</u>	<u>Not Applicable</u>	<u>2</u>
	<u>House floor area ≤ 1,000 ft²</u>	<u>1</u>	<u>1</u>
	<u>House floor area ≥ 2,500 ft²</u>	<u>-1</u>	<u>-1</u>
	<u>Energy Star Fans⁸</u>	<u>1</u>	<u>1</u>
	<u>Install 1 kW or greater of solar electric</u>	<u>1</u>	<u>1</u>
<u>Metal Framed</u>			
	<u>R-13 +R 3 Wall Insulation</u>	<u>0</u>	<u>1</u>
	<u>R-13 cavity Wall insulation + R-0</u>	<u>-1</u>	<u>0</u>
	<u>R-13 Wall Insulation + high reflectance walls⁴</u>	<u>0</u>	<u>1</u>
	<u>R-13 wall insulation + 90% high efficacy lighting and Energy Star Appliances⁵</u>	<u>1</u>	<u>2</u>
	<u>R-13 Wall Insulation + exterior shading wpf=0.3⁶</u>	<u>0</u>	<u>1</u>
	<u>R-30 Roof Insulation</u>	<u>0</u>	<u>1</u>
	<u>R-19 Roof Insulation</u>	<u>-1</u>	<u>0</u>
	<u>R-19 + Cool roof membrane¹ or Radiant Barrier³</u>	<u>0</u>	<u>1</u>
	<u>R-19 Roof Insulation + Attic Venting²</u>	<u>0</u>	<u>1</u>
	<u>Ductless Air Conditioner⁷</u>	<u>1</u>	<u>1</u>
	<u>1.071 X Federal Minimum SEER for Air Conditioner</u>	<u>1</u>	<u>1</u>
	<u>1.142 X Federal Minimum SEER for Air Conditioner</u>	<u>2</u>	<u>2</u>
	<u>No air conditioning installed</u>	<u>Not Applicable</u>	<u>2</u>
	<u>House floor area ≤ 1,000 ft²</u>	<u>1</u>	<u>1</u>
	<u>House floor area ≥ 2,500 ft²</u>	<u>-1</u>	<u>-1</u>
	<u>Energy Star Fans⁷</u>	<u>1</u>	<u>1</u>
	<u>Install 1 kW or greater of solar electric</u>	<u>1</u>	<u>1</u>

¹ Cool roof with three-year aged solar reflectance of 0.55 and 3-year aged thermal emittance of 0.75 or 3-year aged solar reflectance index of 64

² One cfm/ft² attic venting using solar-attic fans

³ Walls with covering with a light reflectance of ≥ 0.64

⁴ Energy Star rated appliances include refrigerators, dishwashers, and clothes washers and must be installed for the Certificate of Occupancy

⁵ The wall projection factor is equal to the horizontal distance from the surface of the wall to the farthest most point of the overhang divided by the vertical distance from the first floor level to the bottom most point of the overhang

⁶ Install ceiling fans in all bedrooms and the largest space that is not used as a bedroom

2.2.4 Simulated Performance Alternative

IECC Table R405.5.2(1) must be amended with energy neutral trade-offs that permit the trade-off of high efficiency heating, cooling and water heating system efficiencies with building envelope features. Refer to Section 6.2.5.

2.2.5 Existing Building Amendments

Requirements for existing buildings shall be amended to be consistent with current Hawaii statutes, including striking language requiring existing building projects to comply with the suite of International Codes. Proposed amendments also provide the ability to meet roof replacement requirements by installing a cool roof as an option to installing additional roof ceiling insulation. Refer to Section 6.2.6.

3 INTRODUCTION

In June 2009, in an effort to achieve the State of Hawaii's goal of meeting 70% of the state's energy needs through renewable energy and energy efficiency by 2030,¹ Hawaii enacted [HB 1464](#) and established an Energy Efficiency Portfolio Standard (EEPS).² The main objective of the EEPS is to reduce electricity demands by 30% through four well-established goals:

- Align the efficiency regulatory policy framework with clean energy goals
- Support the retrofitting of existing residential and commercial buildings
- Strengthen new construction policies and building codes
- Identify non-building related efficiency measures.³

Because Hawaii imports the majority of energy used throughout the state, customers are experiencing the highest electricity prices in the nation at almost three times the U.S. average.⁴ Hawaii's electricity is highly dependent on oil and coal: 71% of Hawaii's electricity is generated using oil and 15% using coal. Furthermore, 28% of the petroleum used in Hawaii is used for electricity production.⁵ Approximately twenty-five percent (25%) of energy use statewide can be attributed to buildings, providing an opportunity to reduce energy consumption through increased efficiencies.

Accordingly, [the Hawaii State Energy Office](#) (HSEO) is strengthening the statewide building codes. Reducing building energy use as well as the demand on resources will contribute to the achievement of Hawaii's goals of increasing energy efficiency and improving energy security.

3.1 CURRENT HAWAII ENERGY BUILDING CODE

In February 2012, the Hawaii State Building Code Council (SBCC) approved the current Hawaii Energy Code (HEC), which is based on the 2009 International Energy Conservation Code (IECC) with Hawaii-specific amendments.⁶ The code was adopted as Chapter 181 of Title 3, Hawaii Administrative Rules, entitled "State Energy Conservation Code."⁷

However, due to a shortage in staff and a lack of funding for an administrative director, the 2009 IECC with amendments did not complete the necessary process, as outlined below, for adoption.

¹ "Report to the 2014 Legislature on Hawaii's Energy Efficiency Portfolio Standard." 1 Dec. 2013. 1 Nov. 2014. <http://puc.hawaii.gov/wp-content/uploads/2013/04/2013-PUC-EEPS-Report_FINAL.pdf>.

² "Hawaii Incentives/Policies for Renewables and Efficiency." *Database of State Incentives for Renewables and Efficiency*. 9 Sept. 2014. 1 Nov. 2014. <http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=HI15R&re=0&ee=0>.

³ "Achieving Efficiency." *Hawaii State Energy Office*. 1 Nov. 2014. <<http://energy.hawaii.gov/energy-efficiency>>.

⁴ "Hawaii State Profile and Energy Estimates." *US Energy Information Administration*. 17 July 2014. 1 Nov. 2014. <<http://www.eia.gov/state/?sid=HI>>.

⁵ "Hawaii Energy Overview." *Hawaii Energy Facts and Figures* (2014).

⁶ "Hawaii Energy Building Code." *Hawaii State Energy Office*. Department of Business, Economic Development and Tourism. 1 Nov. 2014. <<http://energy.hawaii.gov/hawaii-energy-building-code>>.

⁷ "Adoption of Chapter 3-181." *Hawaii State Energy Office*. Department of Accounting and General Services. 1 Nov. 2014. <<http://energy.hawaii.gov/wp-content/uploads/2012/06/2009-IECC-amendments-v9-2012-01-301.pdf>>.

As a result, Hawaii's current energy code, the 2006 HEC, is based on the 2006 IECC with state-specific amendments. Since energy codes are adopted and enforced at the county level, there is often a difference in which code is being enforced. Currently, [Hawaii County](#), [Honolulu County](#) and [Maui County](#) have adopted the 2006 IECC; [Kauai County](#) has adopted the 2009 IECC.

The SBCC and its Energy Code Subcommittee have agreed to update Hawaii's energy code by adopting the 2015 IECC statewide. Previous versions of the IECC have not provided suitable envelope and efficiency requirements for the Hawaiian semi-tropical climate and as such, Hawaii and the US Territories have had to make significant amendments to the IECC to ensure its applicability locally. Although the 2015 IECC now includes Section R401.2.1, Tropical Zone, Hawaii's adoption of the 2015 IECC will also include relevant amendments previously approved by the SBCC to the 2009 IECC as well as amendments to the 2015 IECC as discussed by the SBCC Energy Codes Subcommittee.

3.2 STATE ADOPTION OF ENERGY CODES

The process in which an energy code becomes adopted statewide begins with the adoption of the IECC with amendments by the SBCC. Once adopted by the SBCC, an energy code is brought to the Hawaii Administrative Rules (HAR) for consideration. An energy code that is adopted by HAR is codified as the HEC. Once the amended IECC 2015 is approved by the SBCC, the HSEO expects to move on HAR adoption and the subsequent adoption of the updated HEC by the various counties. However, the counties are allowed to adopt the SBCC approved code prior to HAR adoption.

3.2.1 State Building Construction

Once the SBCC has approved the adoption of an energy code and the code has been codified by HAR, state agencies construct to the code regardless of which county construction of the state building takes place.

3.2.2 Private Construction

Following HAR adoption, the updated code is available for adoption and/or minor amendment by the various county councils. If no action is taken, the code is considered mandatory after twenty-four months.

3.3 COMPLIANCE WITH UNITED STATES DEPARTMENT OF ENERGY DETERMINATION REQUIREMENTS

Both the [International Code Council](#) (ICC) and the [American Society of Heating, Refrigerating and Air-Conditioning Engineers](#) (ASHRAE) perform periodic revisions of current codes and standards through an established process that allows and encourages stakeholder participation from industry, the public and governmental entities. With each new edition of ANSI/ASHRAE/IES Standard 90.1 (Standard 90.1) and the IECC, the United States (U.S.) Department of Energy (DOE) is required by statute to issue a determination as to whether the updated edition will improve energy efficiency in buildings. Upon publication of an affirmative determination, States are required to certify that they have reviewed the provisions of the commercial and residential

building codes regarding energy efficiency, and, as necessary, update their codes to meet or exceed the updated edition of the IECC and Standard 90.1.⁸

On October 19, 2011, DOE issued a final determination that the ANSI/ASHRAE/IES Standard 90.1-2010 (Standard 90.1-2010) would achieve greater energy efficiency in buildings subject to the standard than those built to ANSI/ASHRAE/IES Standard 90.1-2007 (Standard 90.1-2007). On May 17, 2012, DOE also issued a final determination that the 2012 IECC would achieve greater energy efficiency in low-rise residential buildings than previous editions of the IECC.

Because these determinations were published before the two year deadline given to states to file a certification of compliance with Standard 90.1-2007 and the 2009 IECC, DOE has indicated that states may file just one certification to address compliance with both Standard 90.1-2007/2009 IECC and Standard 90.1-2010/2012 IECC determinations.

Additionally, On September 26, 2014, DOE issued a final determination that Standard 90.1-2013 would achieve greater energy efficiency in commercial buildings subject to the standard than those built to previous versions. DOE estimates national savings in commercial buildings of approximately:

- 8.7% energy cost savings
- 8.5% source energy savings
- 7.6% site energy savings.⁹

DOE has also issued a preliminary determination that the 2015 IECC would achieve greater energy efficiency in low-rise residential buildings than those built to previous versions of the IECC.

By adopting an amended 2015 IECC as Hawaii's energy code, the HSEO will demonstrate compliance with DOE's requirement to review the provisions of the commercial and residential building codes and will meet or exceed the most current version of Standard 90.1 and the IECC.

To facilitate DOE's certification requirements, the HSEO has contracted Britt/Makela Group, Inc. (Consultant) to prepare the necessary findings and certifications and, if necessary, to provide recommendations as to the changes or updates needed to bring the HEC into compliance with Standard 90.1-2013 and the 2015 IECC. The Consultant team includes the building energy modeling staff of Synergy Efficient Solutions.

The objective of this report is to provide an analysis of proposed draft amendments to the 2015 IECC to be included in the 2015 HEC.

⁸ "ANSI/ASHRAE/IES Standard 90.1-2013 Determination." *Building Energy Codes Program*. US Department of Energy, 28 Oct. 2014. 1 Nov. 2014. <<http://www.energycodes.gov/determinations>>.

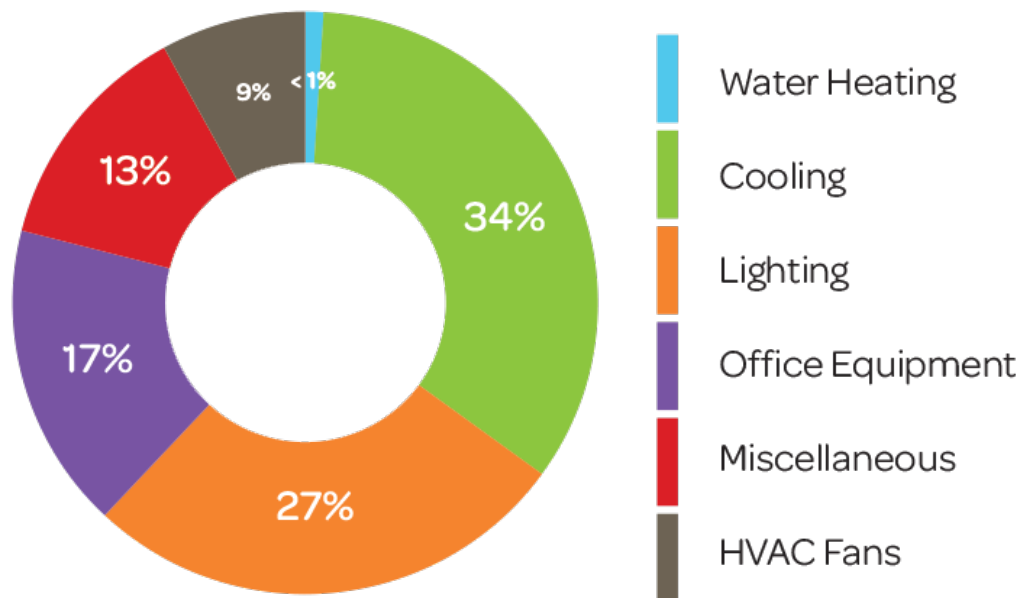
⁹ "2015 International Energy Conservation Code Determination." *Building Energy Codes Program*. US Department of Energy, 28 Oct. 2014. 1 Nov. 2014. <<http://www.energycodes.gov/determinations>>.

4 EVALUATED AMENDMENTS

4.1 COMMERCIAL AMENDMENTS

The figure below, courtesy of [Hawaii Energy](http://www.hawaiienergy.com), illustrates the breakdown of energy use in commercial office buildings. Building energy use varies across commercial occupancies; a hotel or restaurant uses energy differently than an office building, for instance. However, lighting and cooling consistently contribute to over sixty percent (60%) of commercial building energy consumption in Hawaii.¹⁰ As such, building energy code provisions that reduce lighting and cooling loads can provide the greatest impact to commercial energy efficiency.

Figure 1. Typical Energy Use for Office Buildings



Updating the HEC from the 2006 IECC to the 2015 IECC will provide significant savings through cool roof requirements, reduced envelope air leakage, lighting controls and reduced interior lighting power densities, minimum HVAC efficiency and fan power limitation requirements, high efficiency service water heating and energy recovery requirements. In addition, the proposed commercial amendments identified in Table 1 are specific to the local climate and building stock of Hawaii and will further reduce energy use.

¹⁰ "Office Buildings." *Hawaii Energy*. 1 Nov. 2014. <<http://www.hawaiienergy.com/office-buildings>>.

Table 1. Evaluated Commercial Amendments

Sub-Metering	Incorporate SBCC approved 2009 IECC amendment Section 505.7 for sub-metering: In new buildings with tenants, metering shall be collected for the entire building and individually for each tenant occupying 1,000 square feet (total enclosed and unenclosed) (93 m²) or more.
Wall Insulation Alternatives	For high rise residential mass wall and steel frame construction, allow low absorptance finishes in lieu of exterior insulation.
Demand Response	Include applicable sections of the IgCC Section 604, Automated Demand Response Infrastructure.
In-Room Energy Management Systems for Hotels/Motels and Vacation Condominiums	Modify the 2015 IECC Section C405.2.4 to apply to all hotels, motels, and time-share condominiums; include control of HVAC systems; add the requirement for a mechanism that shuts off the HVAC for the room when exterior doors to the room are open.

4.2 RESIDENTIAL AMENDMENTS

The Consultants evaluated Hawaii's amendments to the 2015 IECC for two compliance paths:

- Standard Home- which consists of modifications to IECC Sections R403 (Systems) and R404 (Electrical Power and Lighting Systems) for fully air conditioned production-style homes on small lots.
- Tropical Home- which consists of modifications to IECC Section R401.2.1 (Tropical Zone) for naturally ventilated and mixed-mode homes on larger lots that can take advantage of trade winds.

Approximately 50 percent (50%) of typical household energy use in Hawaii can be attributed to air-conditioning and water heating. ^{[11][12]} As such, the proposed amendments to the 2015 IECC are designed to reduce interior temperatures, reducing the cooling loads of conditioned buildings and making naturally ventilated and semi-conditioned homes more comfortable, and to reduce energy consumption associated with hot water by requiring solar thermal or high efficiency water heaters.

Table 2 summarizes and identifies the applicability of each proposed amendment as it relates to standard and tropical homes.

¹¹ "HVAC." *Hawaii Energy*. 1 Nov. 2014. <<http://www.hawaiienergy.com/hvac-res>>.

¹² "Home Energy Audits." *Hawaii Powered*. 1 Nov. 2014. <<http://www.hawaiicleanenergyinitiative.org/residential-home-energy-audits/>>.

Table 2. Evaluated Residential Amendments

Evaluated Amendment		Applicable to Standard Home	Applicable to Tropical Home
Roof Ventilation	A solar-powered exhaust fan must provide at least one-half cubic foot per minute of airflow for each square foot of roof area.	x	x
	A solar-powered exhaust fan must provide at least one cubic foot per minute of airflow for each square foot of roof area.	x	X
	A solar-powered exhaust fan must provide at least one and one-half cubic foot per minute of airflow for each square foot of roof area.	x	x
Roof Insulation	R-19 with Cool Roofs. Roofing material must have an extended solar absorptance of at most .45 which is accomplished by selecting materials with the application of a roof coating or cladding with a labeled reflectance; must be rated in compliance with the Cool Roof Rating Council's Product Rating Program Manual; must have an infrared emittance of no less than 0.75 when tested in accordance with ASTM E-408; and must have an initial reflectance of no less than 0.70 and an extended reflectance of no less than 0.55.	x	x
	R-19 with Radiant Barrier. A radiant barrier shall have an emissivity of no greater than 0.05 as tested in accordance with ASTM E-408. The radiant barrier shall be installed with the shiny side facing down and with a minimum air gap thickness of ¾ inch below. The radiant barrier may be securely attached to the roof framing or may be laminated to the bottom of the roof sheathing.	x	x
	R-30	x	x
Wall Insulation	No continuous insulation. R-13 cavity insulation with exterior wall color with a natural surface or finished with a paint with an average light reflectance value ≥ 0.64	x	x
	No continuous insulation. R-13 cavity insulation, increased high efficacy lighting to 90%	x	x
	No continuous insulation. R-13 cavity insulation with PF $\geq .30$	x	x
	No continuous insulation. R-13 cavity insulation, increased SEER to 14	x	x
AC Equipment Efficiency	SEER 16	x	x
Fenestration SHGC	PF <.30: SHGC 0.25; PF .30 - .50: SHGC .40; PF ≥ 0.50 N/A		x
Air Leakage	Jalousie windows shall not exceed 1.2 cfm per square foot (6.1 L/s/m ²)		x

5 ANALYSIS

The primary tool used to analyze the impact of the proposed draft amendments to the 2015 IECC was building energy simulation. Building energy simulation, or energy modeling, is not only a valuable tool for understanding the energy use of buildings, but also promotes understanding and interaction among the parties involved in the many phases of the building process. In the context of code development, energy modeling can be used to inform the selection of measures for inclusion in building codes. Modeling can also predict broad impacts of energy saving features incorporated into the building stock. On an individual building project, energy modeling can help a design team compare the relative energy impacts of different design strategies on total energy performance.

Although a strong tool, building energy simulation has limitations and is best augmented by research. Thus, to complement the modeling analysis and provide review of those measures not readily assessed through building energy simulation, the Consultant conducted a literature review and research of comprehensive studies from respected and peer reviewed sources. This information is included throughout Sections 6 and 7 of this report.

5.1 METHODOLOGY

5.1.1 Savings over 2006 HEC Based on Statewide New Construction

Projected energy savings that can be attributed to the proposed code amendments were derived by comparing projected energy use for buildings constructed to the current adopted HEC following Table 402.1.1 of the HEC, and the proposed code amendments to the 2015 IECC, resulting in a percent energy savings. The results of this analysis can be found in Section 7 of this report.

5.1.2 HEC Comparison to 2015 IECC and ASHRAE 90.1-2013

Amending the IECC to better address local climate conditions and/or building practices provides both an opportunity for a more stringent code and a potential for a less stringent code. To best understand how the proposed amendments affect the stringency of the 2015 IECC, a comparison was developed using both quantitative and qualitative analysis. A quantitative analysis compared projected energy use for each building type constructed to the base IECC (residential) and Standard 90.1 (commercial) to the amended IECC. A qualitative analysis was prepared evaluating code measures that cannot be captured through building energy simulation, such as sub-metering commercial properties. The results of this analysis can be found in Section 7 of this report.

5.2 MODELING PROCESS

For this project, the Consultant used the EnergyPlus energy simulation software to evaluate the impact of a range of building efficiency features on the energy use of a set of buildings deemed to represent typical construction practices in Hawaii.

Energy modeling requires detailed data input into the simulation software to represent a prototype building. To simplify this effort, the project team used information from a set of prototype buildings already developed by DOE. These prototypes are intended to be used by

agencies and individuals in the U.S. and abroad as a starting point for research and evaluation projects focusing on building performance. The prototypes also serve as the basis of evaluations of the impact of energy code strategies (called ‘determination analyses’) on the overall energy performance of the building stock.

The modeling analysis performed for this task is consistent with analysis conducted on the amendments approved by the SBCC to the 2009 IECC by Kolderup Consulting and included in the report entitled “Hawaii Building Energy Code Stringency Assessment and Savings Forecast.”¹³

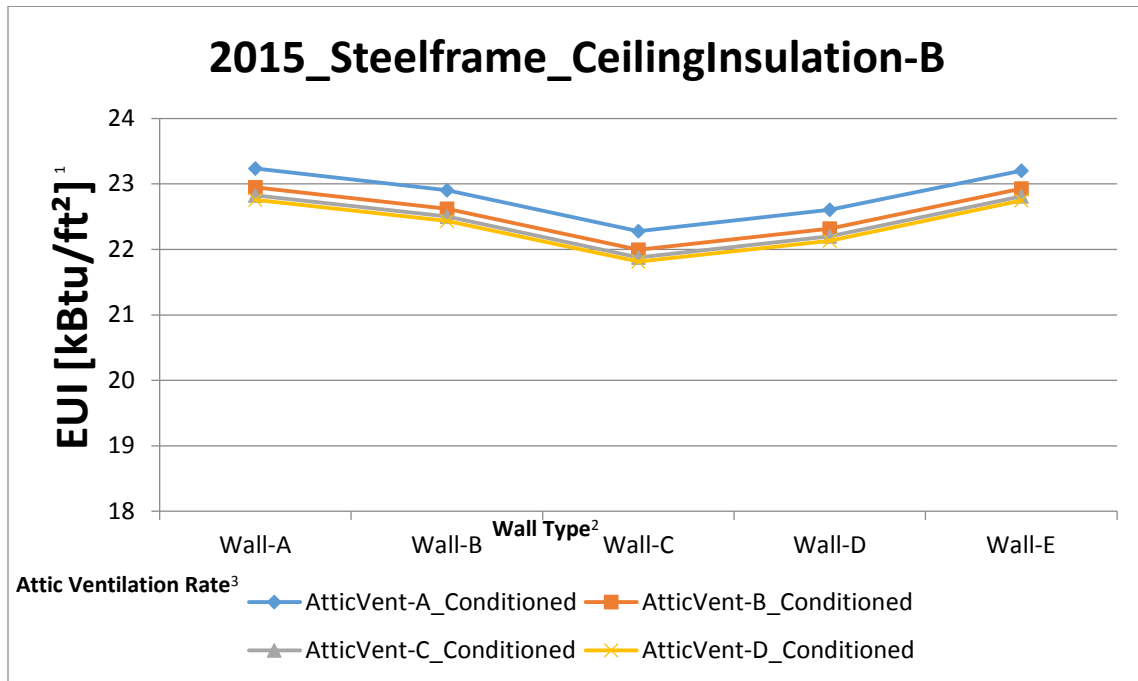
The analysis performed by the Consultant was focused on several key building features and strategies that represent opportunities for the advancement of the building design and construction process in the Hawaiian building industry. Each of the measures evaluated for performance improvements are available through the local market and familiar to the local building trades, although not necessarily generally practiced. For example, although the use of radiant barrier is widespread, it is not universal in the Hawaiian building industry. Therefore, this feature was evaluated to determine if it should be adopted as a basic building requirement.

For each building feature evaluated, a set of parametric runs was developed to demonstrate the impact of a range of characteristics on overall building performance. Each parametric generated a graphic plot of a curve comparing the characteristics of the building feature in question to overall building energy use, represented as energy use intensity (EUI).

An example of a parametric evaluation is presented in Figure 2. This particular evaluation is for the fully conditioned steel frame residential prototype with R-19 ceiling insulation. The y-axis (vertical) measures building EUI with lower values on the y-axis representing lower building energy use. The x-axis (horizontal) represents a series of wall types with which four different attic ventilation rates were compared. The lines generated show that wall insulation alternatives approved by the SBCC as amendments to the 2009 IECC and various levels of attic ventilation have similar resulting energy use, ranging from a low of 21.8 kBtu/ft² for Wall C (R-13 cavity with no exterior insulation) with 1.5 cfm/ft² attic ventilation to a high of 23.2 kBtu/ft² for Wall A (R-13+3) with 2015 IECC code minimum attic ventilation.

¹³ Kolderup Consulting. "Hawaii Building Energy Code Stringency Assessment and Savings Forecast." (2012). 1 Nov. 2014. <http://energy.hawaii.gov/wp-content/uploads/2011/10/Energy-Code-Stringency-Analysis_v5.pdf>.

Figure 2. Sample Parametric Evaluation: Steel Framed Wall with R-19 Ceiling Insulation Compared to Wall Types and Attic Ventilation for Conditioned Buildings



¹ EUI = Energy Use Index (kBtu/ft²)

² Wall Type A: Per code: R13+5 (HEC) and R13+3 (IECC)

Wall Type B: No exterior insulation, high reflectance surface on wall

Wall Type C: No exterior insulation, high efficacy lighting

Wall Type D: No exterior insulation, exterior shading WPF=0.3

Wall Type E: No exterior insulation, SEER 14

³ Attic Ventilation Rate A: Minimum code attic ventilation

Attic Ventilation Rate B: 0.5 cfm/sf

Attic Ventilation Rate C: 1.0 cfm/sf

Attic Ventilation Rate D: 1.5 cfm/sf

Once generated, the results can be evaluated in the context of building practices and product availability and coupled with research and current data on energy use to develop recommendations for code performance levels. The building energy use parametric runs generated for this analysis are included in Appendix A. Although energy use intensity is a good proxy for evaluating building performance, in the case of mixed-mode and naturally ventilated buildings, improvements in the building envelope will not generate direct energy savings because there is no cooling equipment operating in the building. For these cases, an alternate parametric was generated which represents the number of total hours in which the energy model predicts that interior building temperatures will be above general comfort conditions. Just as with the parametric example above, the shape of this curve provides information about the effectiveness of envelope performance strategies on reducing indoor heat gain.

5.2.1 Building Type and Characteristics Methodology

5.2.1.1 Commercial prototypes

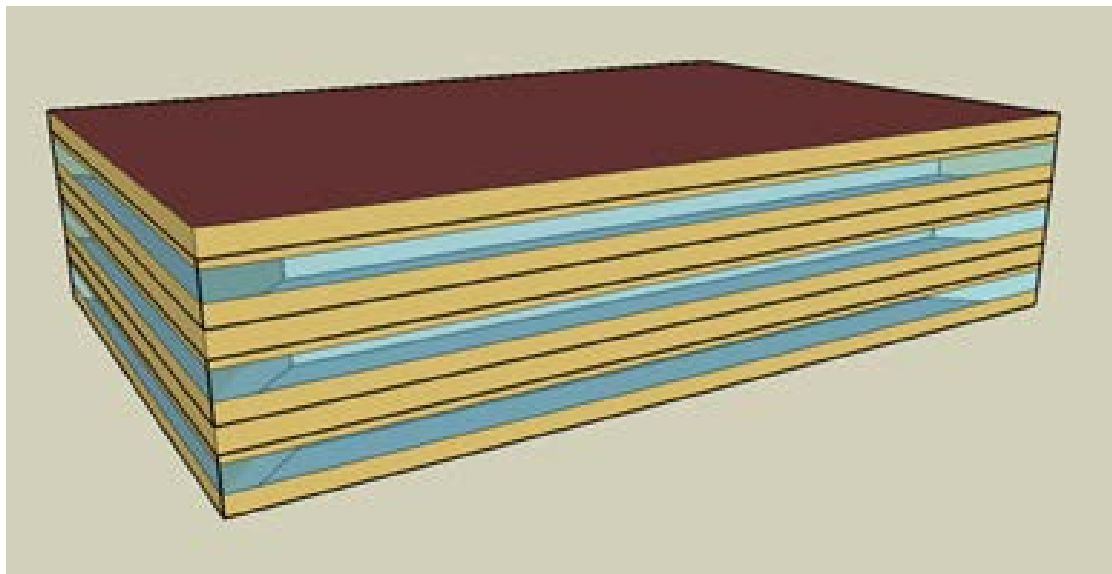
Five DOE commercial building prototypes were selected for this analysis to measure changes in building energy use resulting from the proposed amendments.¹⁴ The prototypes were selected to demonstrate energy use across a variety of building types and occupancies typical in Hawaii. The prototypes also include the type of building typically built to code, as opposed to a beyond code program or green building certification. Additionally, the prototypes include buildings whose energy use can be impacted through building energy codes; buildings whose energy use is primarily reliant on appliance or equipment efficiencies (e.g., supermarkets) were not included in this study. The prototype buildings include:

- Medium Office
- Large Office
- Strip Shopping Center
- Large Hotel
- Large High Rise/Condo

Medium Office

A prototype medium-sized office building was modeled as a three-story structure with an area of approximately 53,500ft². The walls are steel frame with a window area of roughly 33% of total wall area. The building has a built up roof system of roof membrane plus roof insulation plus metal decking. It is built over a slab on grade floor. Air-conditioning is provided via a packaged variable air volume (VAV) system.

Figure 3. Medium Office Prototype

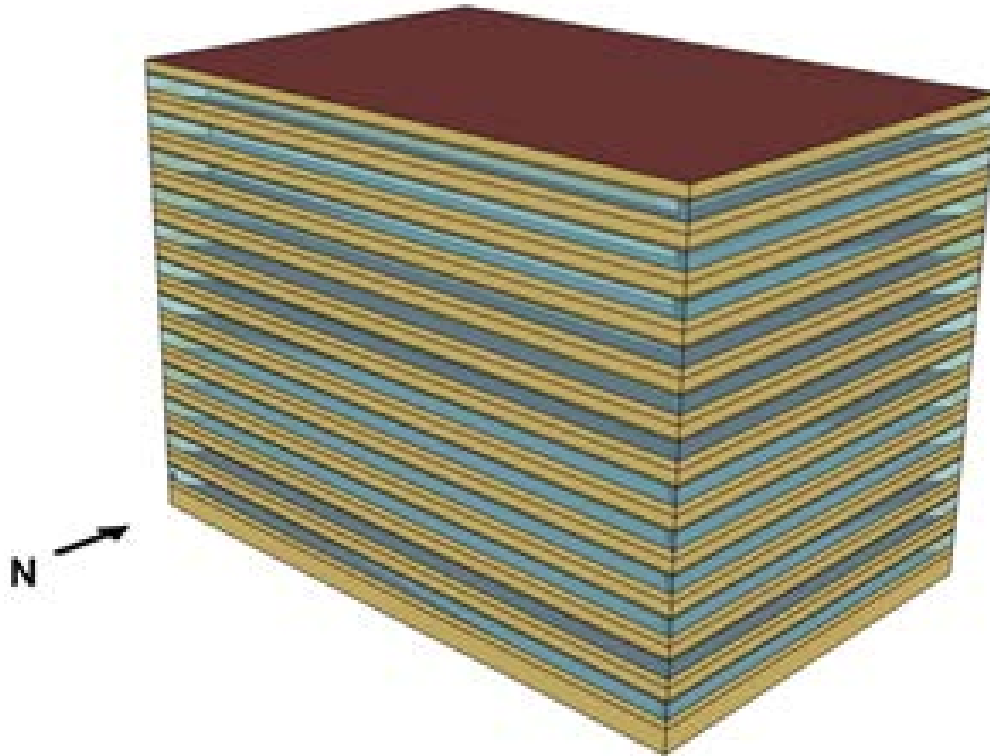


¹⁴ "Commercial Prototype Building Models." *Building Energy Codes Program*. Pacific Northwest National Laboratory. 1 Nov. 2014. <<http://www.energycodes.gov/commercial-prototype-building-models>>.

Large Office

A prototype large-sized office building was modeled as a thirteen-story structure (including basement) with an area of approximately 500,000 ft². The wall construction is mass walls with a window area of roughly 40% of total wall area. The building has a built up roof system of roof membrane plus roof insulation plus metal decking, built over an unconditioned basement floor. Air-conditioning is provided via a VAV system with water source DX cooling and hot-water reheat.

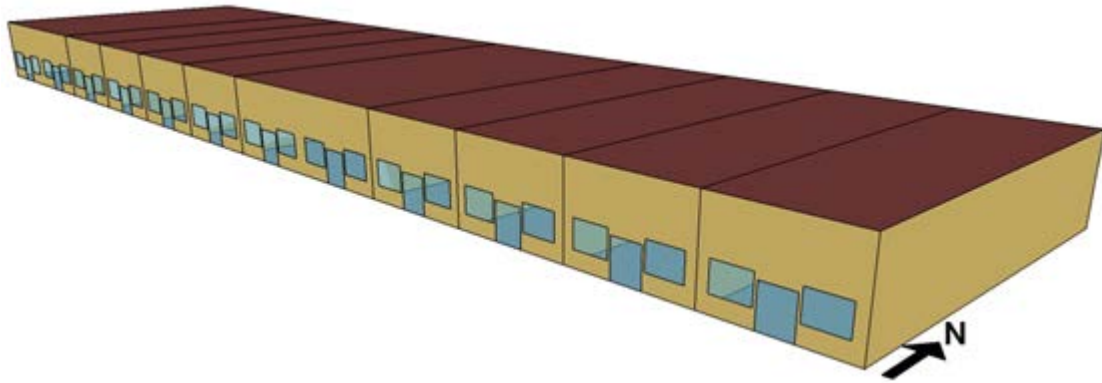
Figure 4. Large Office Prototype



Strip Shopping Center

A prototype strip shopping retail building was modeled as a single-story structure with an area of approximately 22,500 ft². The walls are steel frame with a window area of roughly 10.5% of total wall area. The building has a built up roof system of roof membrane plus roof insulation plus metal decking, built over a slab on grade floor. Air-conditioning is provided via packaged rooftop air-conditioning units.

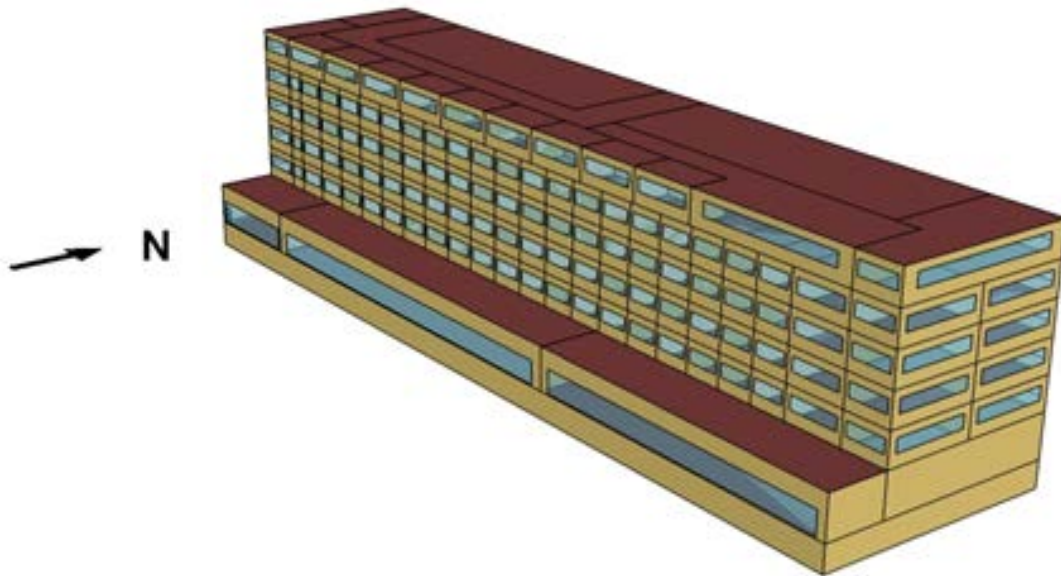
Figure 5. Strip Shopping Center Prototype



Large Hotel

A prototype large hotel building was modeled as a seven-story (including basement) structure with an area of approximately 122,000 ft². The walls are constructed mass walls with a window area average of roughly 30% of total wall area. The building has a roof system of single ply roof membrane plus metal decking with rigid insulation, built over a conditioned basement floor. Air-conditioning is provided via a packaged VAV system in public places on the ground and top floor and dedicated outside air system plus four-pipe fan-coil units in the guest rooms.

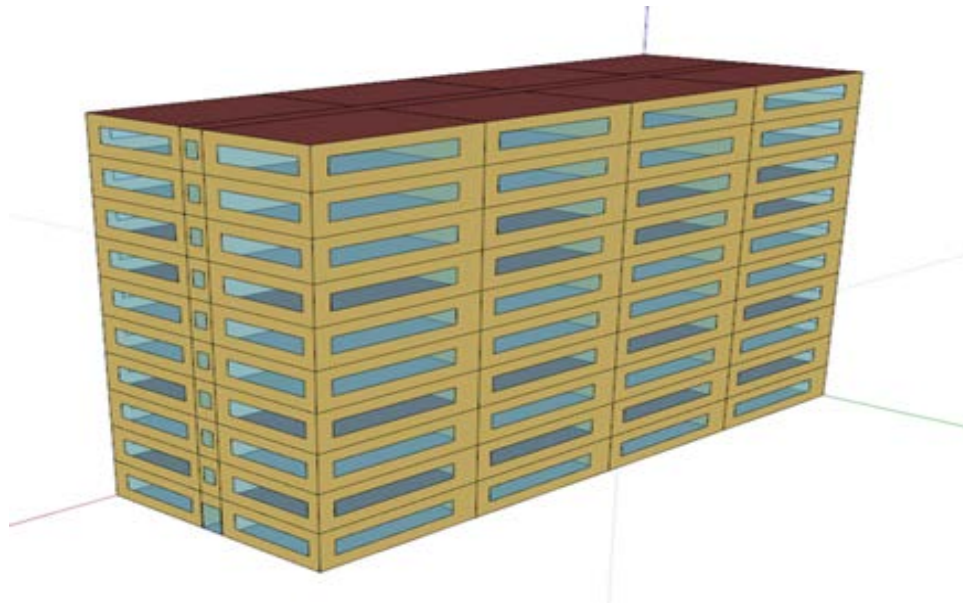
Figure 6. Large Hotel Prototype



Large High-rise Condo/Apartment Building

A prototype large high-rise condo or apartment building was modeled as a ten-story structure with an area of approximately 84,000 ft². The walls are steel frame with a window area average of roughly 30% of total wall area. The building has a built up roof system of roof membrane plus roof insulation plus metal decking, built over a slab on grade floor. Air-conditioning is provided via a water source heat pump.

Figure 7. Large Apartment/Condominium Prototype



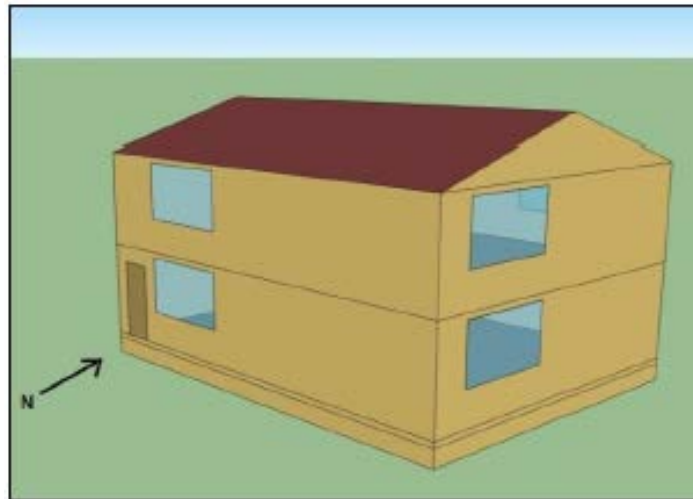
5.2.1.2 Residential Prototype

The residential single family prototype is a two story, 2,400 square foot home. The prototype's thermal zones are determined by which foundation is used: slab on grade, basement or crawlspace. Slab on grade was the assumed foundation for this analysis. The established zones were in Living Unit Floor 1, Living Unit Floor 2 and Attic. The simulations were carried out for conditioned, mixed-mode and naturally ventilated conditions. Both wood and steel framing were assumed. For the conditioned case, both floors of the living units were conditioned. For the mixed-mode case, only the second floor of the living unit was conditioned.¹⁵ The building assemblies between the conditioned and unconditioned spaces were assumed to be uninsulated. This prototype has gabled roofs with a 4:12 roof slope. Roof construction is assumed to be medium colored asphalt shingles with ceiling insulation placed entirely in the attic on the attic floor. The attic is considered to be vented per the provisions of the International Residential Code (IRC). The floors are assumed to have wood joists spaced 24 inches on center. The ceiling, wall, and floor insulation levels are modeled according to the IECC code requirements for each code year. Vertical fenestration for the single-family prototype is configured as a 15 percent (15%) window-to-floor ratio (WFR) distributed equally along all cardinal directions. The prototypes do not account for

¹⁵Todd Taylor, Nick Fernandez, and Robert Lucas. "Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes." (2012). *Building Energy Codes Program*. 1 Nov. 2014.
<http://www.energycodes.gov/sites/default/files/documents/residential_methodology.pdf>.

external shading geometry although shading was considered for this analysis. No skylights are included in the prototypes.¹⁶

Figure 8. Residential Prototype



5.2.1.2.1 Modifications for Natural and Semi-Conditioned Homes

To evaluate the effect of proposed amendments on the natural and semi-conditioned homes, the prototype was modified in accordance with the 2015 IECC Section R401.2.1 to include the following key features:

- Not more than one-half of the occupied space is air conditioned
- At least 90% of the energy for service water heating is supplied by a solar, wind or other renewable energy source
- Operable fenestration provides ventilation area equal to at least 14% of the floor area of each room
- Glazing in conditioned space has a solar heat gain coefficient (SHGC) of less than or equal to 0.25 or has an overhang with a projection factor equal to or greater than 0.30
- Bedrooms with exterior walls facing two different directions have operable fenestration or exterior walls facing two directions.

5.3 MEASURES EVALUATED

For this task, the following key building parameters were evaluated as a focus of efforts to strategically amend the IECC for adoption in Hawaii:

- Radiant Barriers
- Cool Roofs
- Roof Insulation
- Attic Ventilation

¹⁶ S. Goel, R. Lucas, and V. Mendon. "Cost-Effectiveness Analysis of the 2009 and 2012 IECC Residential Provisions – Technical Support Document." (2013). *Building Energy Codes Program*. Pacific Northwest National Laboratory. 1 Nov. 2014. <http://www.energycodes.gov/sites/default/files/documents/State_CostEffectiveness_TSD_Final.pdf>.

- Wall Insulation
- Cooling Systems Controls
- Cooling Equipment Efficiencies

Each measure was evaluated in the context of each of the building prototypes with the exception of the cool roof analysis. Section 6 of this report includes qualitative and technical findings including parametric analysis of the proposed amendments. The results are summarized based on the combined results of the different building types and savings are generalized based on the range of savings across building types.

6 FINDINGS AND RECOMMENDATIONS FOR AMENDING THE 2015 IECC

6.1 COMMERCIAL AMENDMENTS

The 2015 IECC commercial provisions reflect many of Hawaii's energy objectives and as such, few amendments are needed. Many of the proposed amendments include measures that address energy use controls, such as door switches, sub-metering, lighting controls for specific applications, and automated demand response. The amendments also address the building envelope and include the addition of provisions for low-energy use buildings and modifications to wall insulation and SHGC requirements. Analysis of these amendments was based on research and, when applicable, building energy simulation.

Additional amendments that address the scope and administration of the IECC, as well as amendments to existing building requirements, are also included.

Code language and IECC section numbers are listed for each proposed amendment below. When available, changes to the original code language are illustrated by either strikethrough text to denote the word or sentence is deleted or underlined text to identify when a word or paragraph has been added.

6.1.1 Scope and Administration Amendments

6.1.1.1 *Title*

Amend IECC Section 101.1 to read as follows:

101.1 Title. This code shall be known as the [~~International~~] Energy Conservation Code of the State of Hawaii, and shall be cited as such. It is referred to herein as "this code."

Discussion: The amendment replaces existing language for construction document requirements with Hawaii specific requirements to be consistent with other adopted building codes.

6.1.1.2 *Construction Documents*

Delete and replace Section C103.1 of the IECC with the following:

103.1 General. When the requirements in this code apply to a building as specified in Section C101.4, plans, specifications or other construction documents submitted for a building, electrical or plumbing permit required by the jurisdiction shall comply with this code and shall be prepared, designed, approved and observed by a design professional. The responsible design professional shall provide on the plans a signed statement certifying that the project is in compliance with this code.

Exception: Any building, electrical or plumbing work that is not required to be prepared, designed, approved or observed by a licensed professional architect or engineer pursuant to chapter 464 Hawaii Revised Statutes.

Discussion: The amendment replaces existing language for construction document requirements with Hawaii specific requirements to be consistent with other adopted building codes.

6.1.2 All Buildings

6.1.2.1 Low-Energy Use Buildings

Amend IECC Section C402.1.1 to read as follows:

C402.1.1 Low-energy use buildings. The following low energy buildings, or portions thereof separated from the remainder of the building by building thermal envelope assemblies complying with this section, shall be exempt from the building thermal envelope provisions of Section C402.

1. Those with a peak design rate of energy usage less than 3.4 Btu/h-ft² (10.7 W/m²) or 1.0 watt per square foot (10.7 W/m²) of floor area for space conditioning purposes.
2. Unconditioned space that does ~~Those that do not contain conditioned~~ habitable space.
3. Greenhouses.

Discussion: The amended language ensures that habitable space, even if unconditioned, will be covered by the provisions of the energy code to increase occupant comfort and reduce the possibility of installing air conditioning in the future.

6.1.2.2 Thermal Resistance of Above-Grade Walls

Amend Section C402.2.3 of the IECC to read as follows:

C402.2.3 Thermal resistance of above-grade walls. The minimum thermal resistance (R-value) of materials installed in the wall cavity between framing members and continuously on the walls shall be as specified in Table C401.3, based on framing type and construction materials used in the wall assembly.

Exceptions: Continuous insulation for wood and metal framed walls are not required when one of the following conditions are met:

1. Walls have a covering with a reflectance of ≥ 0.64
2. Walls have overhangs with a projection factor equal to or greater than 0.3. The projection factor is the horizontal distance from the surface of the wall to the farthest most point of the overhang divided by the vertical distance from the first floor level to the bottom most point of the overhang.

The R-value of integral insulation installed in concrete masonry units shall not be used in determining compliance with Table C402.1.3.

Mass walls shall include walls:

1. Weighing not less than 35 psf (170 kg/m²) of wall surface area.
2. Weighing not less than 25 psf (120 kg/m²) of wall surface area where the material weight is not more than 120 pcf (1900 kg/m³).
3. Having a heat capacity exceeding 7 Btu/ft²·°F (144 kJ/m²·K).
4. Having a heat capacity exceeding 5 Btu/ft²·°F (103 kJ/m²·K), where the material weight is not more than 120 pcf (1900 kg/m³).

Discussion: Modeling was conducted on the commercial wall permutations indicated in Table 3.

Table 3. Commercial Wall Permutations

Wall Description	Permutation
Mass Wall	
Set A	Base, with R-4 exterior wall Insulation
Set B	Replace exterior wall insulation with exterior wall Reflectance ≥ 0.64
Steel Frame	
Set A	Base, R-13 Insulation
Set B	Replace exterior wall insulation with Exterior Wall Reflectance ≥ 0.64

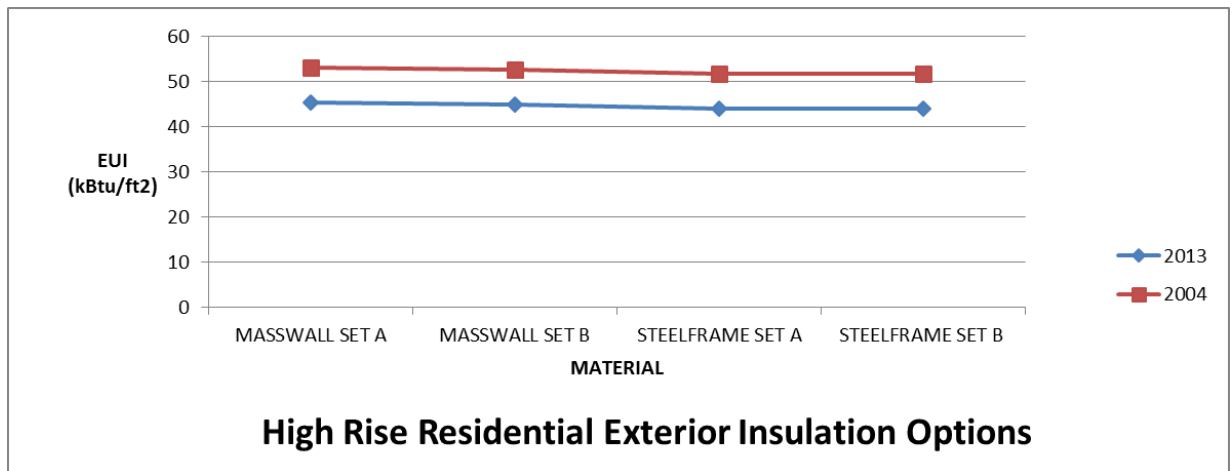
The analysis shows that R-13 is the most impactful level of insulation for residential buildings and that removing continuous insulation on steel frame walls does not significantly impact whole building energy use. Adding shading to the wall system with a projection factor of at least 0.3 eliminates the need for continuous insulation in exterior wall systems resulting in an energy equivalent installation. In a tropical climate, the impact of wall insulation is diminished for commercial buildings with more importance placed on roof insulation and window SHGC. Envelope trade-offs for residential construction can be extrapolated to commercial construction for wall systems allowing the trade-off for a projection factor on wall systems to work for both residential and commercial buildings.

Adding reflective coatings on wall systems is also an effective trade-off for continuous insulation in residential exterior wall systems. As with the projection factor, this trade-off can be transferred to commercial buildings as an energy neutral trade-off. Analysis indicates that exterior reflectance is a suitable replacement for insulation, resulting in similar energy use indices, as illustrated in Table 4 and Figure 9.

Table 4. Potential Energy Savings, Mass and Steel Frame High Rise Residential Wall Insulation Levels

Alternative	EUI (kBtu/ft ²)	
	ASHRAE 2013	ASHRAE 2004
Mass wall Base Case	45.39	53.24
Mass wall Set B	44.96	52.77
Steel frame base case	44.09	51.86
Steel frame Set B	44.07	51.86

Figure 9. Parametric Illustration Impacts of Exterior Wall Insulation Options



6.1.2.3 Area-weighted SHGC

Add Section C402.4.3.5 to the IECC to read as follows:

C402.4.3.5 Area-weighted SHGC. In commercial buildings, an area-weighted average of fenestration products shall be permitted to satisfy SHGC requirements.

Discussion: Modeling by the National Renewable Energy Laboratory indicated that shading fenestration was as effective as SHGC requirements in Hawaii’s mild climate. Area weighting allows trade-offs between fenestration SHGC allowing a higher SHGC to be installed on the North elevation and offsetting that with lower SHGC requirements for windows on the East, West and South.

6.1.2.4 Door Switches

Add Section C403.2.4.2.3 to the IECC to read as follows:

C403.2.4.2.4 Door switches. Opaque and glass doors opening to the outdoors in hotel and motel sleeping units, guest suites and time-share condominiums, shall be provided with controls that disable the mechanical cooling, or reset the cooling setpoint to 90° F or

greater within five minutes of the door opening. Mechanical cooling may remain enabled if the outdoor air temperature is below the space temperature.

Discussion: In-Room Energy Management Systems are wireless devices installed in hotel rooms that control the HVAC and lighting of the room. The system is activated when a guest in a hotel slips the hotel key card into the “dock” located by the front door. The key enables lighting and HVAC controls in the room to be available to the guest. Once the key card has been taken out of the dock, the HVAC and lighting will resume the default energy saving mode.

Additionally, HVAC smart relay systems with window and patio door sensors send signals to the HVAC unit when the window or patio door is open. The signal will communicate with the HVAC system, turning off the system and resuming default energy saving mode while the patio door or window is open. When the window or patio door is shut, the signal communicates to the HVAC system and resumes the occupants’ desired settings.

The proposed change would require automatic controls that reset the cooling system temperature in a hotel and motel sleeping unit, guest suites and time share condominiums when doors to the outdoors are left open. A similar requirement is contained in ASHRAE 90.1-2013 Section 6.5.10.

Analysis and Recommendation: Research indicates that there is a potential for significant savings when in-room energy management systems are employed. A study by Pacific Gas and Electric¹⁷ as well as research by Magnum Energy Solutions,¹⁸ found that key card energy control systems provided an estimated savings of 35% - 45% per room. Additionally, prior research conducted for the State of Hawaii indicated that occupancy-based guest room controls could provide at least 5% savings for the entire hotel.¹⁹

A study conducted in 2002 by Jeff Stein of Taylor Engineering and created for the California Statewide Utility Codes and Standards Program²⁰ estimated savings of almost 60% for operable windows and/or doors with switches versus operable windows and/or doors without switches.

6.1.2.5 Specific Application Controls

Amend IECC Section C405.2.4 to read as follows:

C405.2.4 Specific application controls. Specific application controls shall be provided for the following:

1. Display and accent light shall be controlled by a dedicated control that is independent of the controls for other lighting within the room or space.
2. Lighting in cases used for display case purposes shall be controlled by a dedicated control that is independent of the controls for other lighting within the room or space.

¹⁷ Donald J. Frey and John Arent. "Card-Key Guestroom Controls Study." (2009). Pacific Gas and Electric Company: Emerging Technologies Program. 1 Nov. 2014. <<http://www.etcc-ca.com/sites/default/files/OLD/images/card-key-1.pdf>>.

¹⁸ Magnum Energy Solutions. "Wireless Energy Management in Hotels." (2012). 1 Nov. 2014. <[www.magnumenergysolutions.com/uploads/WhitePaper\(1\).pdf](http://www.magnumenergysolutions.com/uploads/WhitePaper(1).pdf)>.

¹⁹ Kolderup Consulting, Stringency Assessment

²⁰ Jeff Stein. "2016 Title 24 Codes & Standards Enhancement (CASE) Proposal: Window and Door Switches." CEC Pre-Rulemaking Workshop. 12 June 2014. Lecture. <http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-06-12_workshop/presentations/Door-Window_Switches.pdf>.

3. Hotel and motel sleeping units ~~and~~, guest suites and time-share condominiums shall have a master control device that is capable of automatically switching off all installed luminaires and switched receptacles within 20 minutes after all occupants leave the room.

Exception: Lighting and switched receptacles controlled by captive key systems.

4. Supplemental task lighting, including permanently installed under-shelf or under cabinet lighting, shall have a control device integral to the luminaires or be controlled by a wall-mounted control device provided that the control device is readily accessible.
5. Lighting for nonvisual applications, such as plant growth and food warming, shall be controlled by a dedicated control that is independent of the controls for other lighting within the room or space.
6. Lighting equipment that is for sale or for demonstrations in lighting education shall be controlled by a dedicated control that is independent of the controls for other lighting within the room or space.

Discussion: The current 2015 IECC code language only includes a master control device for hotel and motel sleeping units and guest suites. Time share condominiums are added to the requirements because they have the same transient use pattern as a hotel and motel overnight room and the energy savings potential will be similar.

6.1.2.6 *Sub-metering (Mandatory)*

Add Section C405.10 to the IECC to read as follows:

C405.10 Sub-metering (Mandatory). In new buildings with tenants, metering shall be collected for the entire building and individually for each tenant occupying 1,000 ft² (total enclosed and unenclosed) (93 m²) or more. Tenants shall have access to data collected for their space. A tenant is defined as “one who rents or leases from a landlord.”

Discussion: Numerous studies indicate that sub-metering, combined with tenant access to consumption data, results in substantial energy use reduction and is cost effective. Metering provides multi-faceted means to reducing energy, including:

- Enabling monitoring based commissioning
- Identifying and monitoring efficiency retrofits
- Aligning incentives and enabling behavioral conservation and
- Supporting peak demand reduction.

The energy use associated with metering varies by building size, type of energy use and purpose for which it is used.²¹ Case studies provide examples of significant savings associated with metering; however, because of the numerous factors involved, there is not a designated range of energy reduction that can be assumed from metering. At a minimum, metering results in tenant

²¹ Buildings Technology Research and Development Subcommittee. "Submetering of Building Energy and Water Usage." (2011). National Science and Technology Council Committee on Technology. 1 Nov. 2014. <<http://www.bfrl.nist.gov/buildingtechnology/documents/SubmeteringEnergyWaterUsageOct2011.pdf>>.

accountability for energy use. One related case study highlighted by the Institute for Market Transformation illustrates this point:

The Bank of America Building in San Francisco was retrofitted with 120 tenant sub meters when it was discovered that the tenant's square footage rate was being exceeded by 300%, and the owner recovered approximately \$1 million in energy costs in the first year after installation.²²

6.1.2.7 Automated Demand Response

The consultants recommended amending the IECC to include automated demand response but requiring the technology for all new commercial buildings was deemed not feasible at this point in time. The consultants proposed, amending the 2015 IECC to include applicable sections of the IgCC Section 604, Automated Demand Response Infrastructure.

Discussion: The Federal Energy Regulatory Commission (FERC) estimated the contribution from existing U.S. demand response resources at about 41,000 megawatts (MW), or approximately 5.8% of the 2008 summer peak demand. FERC also estimated the nationwide achievable demand response potential at 138,000 MW (14% of the peak demand) by 2019, which is a significant savings. Participating in demand response programs will also reduce the energy use and cost to operate the building during peak periods when power is at its most expensive.

As currently written, key requirements of the IgCC Section 604 are as follows:

Automated demand response (Auto-DR) control systems are required for all buildings with HVAC systems. Each HVAC system must be able to receive an open and interoperable automated demand response relay or an internet signal. The two primary requirements for such systems are:

- Reducing the building peak cooling or heating HVAC demand by a minimum of 10 percent (10%) when the system receives a signal.
- Providing controls that slowly bring the system back on line to prevent a “rebound peak” (i.e., creating a peak demand by bringing all of the systems back on line too quickly, thereby pushing the grid back to near capacity).

The code provides four exemptions for this requirement:

- Buildings located where the electric utility, Independent Service Operator, or Regional Transmission Operator does not offer a demand response program to commercial buildings. There are no energy cost savings for the building owner under these circumstances.
- Buildings with a peak electric demand less than 75% of the standard reference design. Auto-DR is not cost effective in these cases.
- Buildings that have on-site renewable energy generation of 20% or more of the total building’s energy demand. Auto-DR is not cost effective under these circumstances.
- Group R Occupancies.

²² Institute for Market Transformation. "Commercial Energy Policy Toolkit - Submetering." 1 Nov. 2014. <http://www.imt.org/uploads/resources/files/Commercial_Energy_Policy_Fact_Sheet_-_Submetering.pdf>.

Auto-DR programs offer incentives to electricity users to reduce their power use in response to a utility's need for power due to a high, system-wide demand for electricity, or emergencies that could affect the transmission grid. For example, during a period of particularly hot weather that results in high air-conditioning use and high utility system demand, the utility could send a signal out to turn HVAC systems down or off in a building. Participating in demand response programs will reduce the energy use and cost to operate the building during peak periods when power is at its most expensive.

The Auto-DR requirements use a strategy specified by the designer which can include:

- Adjusting the interior design temperature up or down based on the season
- Disabling HVAC systems in parts of the building that are unoccupied
- Increasing or decreasing the supply air temperature of a VAV system

Analysis and Recommendation: A case study of the Eastern South Dakota and Western Minnesota East River Electric Power Cooperative illustrates savings of wholesale power cost of almost \$90 million over 22 years. Since the implementation of the program, the region has experienced steady load growth that has resulted in the allocation of power provided by Western Area Power Administration being reduced from 50% to approximately 25% of its entire load served.

Twenty-five years ago, the East River System was experiencing farm closures and wholesale power cost increases which encouraged the implementation of a Load Management system (Auto-DR) to control wholesale power costs. The objective was peak load reduction to avoid wholesale power purchases on behalf of the distribution cooperatives.

The East River member cooperative's Auto-DR system has been operating for over 22 years. Over 60,000 different electric loads in homes, farms and businesses of member consumers throughout eastern South Dakota and western Minnesota are connected to the system. These loads include electric water heaters, air conditioners, irrigation systems and large industrial processes. Control is initiated monthly through a highly sophisticated system that communicates with control receivers connected to the various loads.

Customers interested in Auto-DR can enroll through their distribution cooperative. Upon enrollment, load control equipment is installed and operated remotely by East River system operators. Customers then receive monthly bill credits for participation in the program. While most residential participants are unaware when the utility is cycling their use, industrial and irrigation customers are more likely to experience a disruption of service.

The Consultant recommends continued collaboration between the HEO, Hawaiian Electric Company and/or Kauai Island Utility Cooperative to develop an appropriate, simplified modification of IgCC Section 604 for adoption, as noted in Section 6.1.1.2.

6.1.3 Existing Building Amendments

6.1.3.1 Compliance

Amend Section C501.4 to read as follows:

C501.4 Compliance. *Alterations, repairs, additions and changes of occupancy to, or relocation of, existing buildings and structures shall comply with the provisions and*

~~regulations for alterations, repairs, additions and changes of occupancy or relocation, as adopted by the authorities having jurisdiction. respectively, in the International Residential Code, International Building Code, International Fire Code, International Fuel Gas Code, International Mechanical Code, International Plumbing Code, International Property Maintenance Code, International Private Sewage Disposal Code and NFPA 70.~~

Discussion: The proposed amendment strikes language requiring existing building projects to comply with the suite of International codes when these codes may not have been adopted by the local jurisdiction. This amendment is consistent with Hawaii Revised Statutes 107-25.

6.1.3.2 *Roof Replacement*

Section C503.3.1 is amended to read as follows (note that options are provided for this amendment):

C503.3.1 Roof replacement. *Roof replacements shall comply with Table C402.1.3 or C402.1.4 where the existing roof assembly is uninsulated and is part of the *building thermal envelope*. ~~and contains insulation entirely above the roof deck.~~*

Discussion: The proposed language will ensure that roofs for existing buildings that are currently not insulated will meet the requirements of the IECC as part of a roof replacement. This will increase the efficiency of the commercial buildings.

6.2 RESIDENTIAL AMENDMENTS

Due to Hawaii's unique climate zone and building practices, several amendments are needed for both fully-conditioned and semi-conditioned/tropical zone homes to fully meet Hawaii's energy objectives. The proposed amendments include provisions for ceiling fans and solar water heaters. The amendments also address the building envelope and include the addition of provisions for low-energy use buildings and modifications to wall insulation and SHGC requirements. Analysis of these amendments was based on research and, when applicable, building energy simulation.

Additional amendments that address the scope and administration of the IECC, inclusion of a points-based option, and changes to the performance option and existing building requirements are also included.

Code language and IECC section numbers are listed for each proposed amendment below. When available, changes to the original code language are illustrated by either strikethrough text to denote the word or sentence is deleted or underlined text to identify when a word or paragraph has been added.

6.2.1 Scope and Administration

6.2.1.1 *General*

Delete IECC section R103.1 in its entirety and replace with the following:

R103.1 General. When the requirements in this code apply to a building as specified in Section R101.4, plans, specifications or other construction documents submitted for a building, electrical or plumbing permit required by the jurisdiction shall comply with this code and shall

be prepared, designed, approved and observed by a design professional. The responsible design professional shall provide on the plans a signed statement certifying that the project is in compliance with this code.

Exception: Any building, electrical or plumbing work that is not required to be prepared, designed, approved or observed by a licensed professional architect or engineer pursuant to chapter 464 Hawaii Revised Statutes.” (Auth: HRS §107-29) (Imp: HRS §§107-24, 107-25)

Discussion: The amendment replaces existing language for construction document requirements with Hawaii specific requirements to be consistent with other adopted building codes.

6.2.1.2 Project Compliance Requirement

Amend Section R401.2 to read as follows:

R401.2 Compliance. Projects shall comply with one of the following:

1. Sections R401.3 through R404
2. Sections R405 and the provisions of Section R401 through R404 labeled “Mandatory.”
3. An energy rating index (ERI) approach in Section R406.
4. The Tropical zone requirements in Section R401.2.1.

Discussion: The amendment provides clarifying language on the options available to the code user and specifically references the Tropical zone requirements as an option.

6.2.1.3 Prescriptive Building Thermal Envelope Requirements

Amend Section R402.1 of the IECC to read as follows:

C402.1.1 Low-energy use buildings. The following low energy buildings, or portions thereof separated from the remainder of the building by building thermal envelope assemblies complying with this section, shall be exempt from the building thermal envelope provisions of Section R402.

1. Those with a peak design rate of energy usage less than 3.4 Btu/h-ft² (10.7 W/m²) or 1.0 watt per square foot (10.7 W/m²) of floor area for space conditioning purposes.
2. Unconditioned space that does ~~Those that do~~ not contain ~~conditioned~~ habitable space.

Discussion: The amended language ensures that habitable space, even if unconditioned, will be covered by the provisions of the energy code to increase occupant comfort and reduce the possibility of installing air conditioning in the future.

6.2.2 Fully-Conditioned Homes

6.2.2.1 Specific Insulation Requirements

Amend Section R402.2 of the IECC to read as follows:

R402.2 Specific insulation requirements (Prescriptive). In addition to the requirements of Section R402.1, insulation shall meet the specific requirements of Sections R402.2.1 through R402.2.13.

Exception: Above-grade walls and ceilings shall be permitted to comply with Section R407.

Discussion: The addition of a Points Option (see Section 6.2.4 for details) provides energy neutral trade-offs allowing efficiencies in the wall system to be traded-off with increased efficiency levels in other parts of the building. This will allow a prescriptive trade-off for continuous insulation in metal framed walls to be traded off with reflective paint on the walls or shading the walls with an overhang.

Alternatives for wall insulation will be permitted depending upon the assembly type and exterior shading such that:

- ***Wood Frame Walls: Wall insulation measured at R-13 is required on exterior walls***

No exceptions are provided for wood framed walls with R-13 cavity insulation.

- ***Steel Frame Walls: Wall insulation measured at R-13/3 is required on the exterior wall of all mechanically cooled spaces***

Exception: For steel frame walls only, exterior insulation may be eliminated when one of the following conditions are met:

- Walls with an overhang $pf \geq .3$
- Exterior wall color with a natural surface or finished with a paint with an average light reflectance value ≥ 0.64 (garages, trim and other non-wall components are exempt)
- The building is equipped with central air-conditioning with a minimum SEER rating 1.0769 times greater than the prevailing federal minimum efficiency.

Analysis and Recommendation: Modeling analysis shows that R-13 is the most impactful level of insulation and that removing the exterior insulation on steel frame walls does not significantly impact whole building energy use. The following wall assembly insulation options were modeled:

- 2006 HEC as a baseline
- 2009 SBCC approved 2009 IECC amendment footnote K from Table 402.1.1 for Mass wall and Wood frame
- 2009 SBCC approved 2009 IECC amendment Section 402.2.5 for Steel frame assemblies.

The options were modeled for both fully conditioned and multi-modal conditioning. Table 5 illustrates the results for conditioned spaces. The results indicate that steel frame walls 24 inches on center without exterior insulation produce similar energy use to wood frame walls and steel frame walls 16 inches on center with standard insulation.

Table 5. Wall Assemblies, Fully Conditioned, Compared to 2006 HEC 24.61 kBtu/ft²

		Wood Frame Fully Condition	Wood Frame Semi Condition	Steel Frame Fully Condition	Steel Frame Semi Condition
1	Table 402.1.1 without footnote, Wall insulations as specified	22.73	20.25	22.90	19.48
2	No exterior insulation on wall, 90% high efficacy light	21.97	20.39	23.24	19.64
3	No exterior insulation on wall, Exterior wall reflectance=0.64	22.44	19.73	21.73	18.82
4	No exterior insulation on wall, External shading PF=0.3	22.25	20.11	22.61	19.30
5	No exterior insulation on wall, SEER 14 A/C	22.90	20.82	23.20	19.76

6.2.2.2 *Ceiling Fans (Mandatory)*

Amend Section R404.2 of the IECC to read as follows:

R404.2 Ceiling Fans (Mandatory). A ceiling fan or ceiling fan rough-in is provided for bedrooms and the largest space that is not used as bedroom.

Discussion: The effect of ceiling fans can be significant in increasing thermal comfort for the occupants of the space. Ceiling fans result in a perceived cooling effect of 5.4°F to 12.6°F based on fan speed (air speed of approximately 3.3 ft/s to 9.84 ft/s respectively). Ceiling fans, coupled with the thermal envelope requirements will reduce the need to cool the space with traditional air conditioning (see ceiling fan discussion in Section 6.2.3.1). At a minimum, the ceiling fan rough-in would allow the home owner to easily install a ceiling fan after the house is occupied. The cost of the installation would include only the cost of the fan and installation. Without the rough-in the cost would include providing power to the fan location in addition to support for the fan which could be a barrier to installing fans in the house.

6.2.2.3 *Solar Water Heating (Mandatory)*

Add Section R403.5.4 to the IECC to read as follows:

Section R403.5.5 Solar water heating. Solar water heating systems are required for new single-family residential construction pursuant to HRS 196-6.5.

Discussion: Solar systems per HRS 196-6.5 are specified to be consistent with state legislation. This requirement is repeated in Section R403.5.5 Solar water heating for fully conditioned buildings to ensure that code users are aware of the requirements. The current solar water heating requirement in R401.2.1 Tropical zone was increased from 80% to 90% to be consistent

with state legislation. The consultant recommended the following language for inclusion in the code consistent with HRS 196-6.5.

Solar energy source supplies not less than 90 percent (90%) of the energy for service water heating, forced circulation or thermosiphon design which contains potable water.

Exceptions: A solar water heating system is not required under the following circumstances if certified by an architect or mechanical engineer licensed under HRS chapter 464: (1) Installation is impracticable due to poor solar resource; or (2) Installation is cost-prohibitive based upon a life cycle cost benefit analysis that incorporates the average residential utility bill and the cost of the new solar water heater system with a life cycle that does not exceed fifteen years; or (3) A renewable energy technology system, as defined in HRS section 235- 12.5, is substituted for use as the primary energy source for heating water; or (4) A demand water heater device approved by Underwriters Laboratories, Inc., is installed provided that at least one other gas appliance is installed in the dwelling.

Analysis and Recommendation: Utilizing 90% renewable energy for domestic hot water heating significantly impacts energy use. In all scenarios, energy use for domestic hot water is reduced from approximately 7264.65 kBtu to 726.47 kBtu annually.

It is also recommended that Chapter 2 of the 2015 IECC be amended to include the following definition:

On-demand water heater. A gas-tankless instantaneous water heater that provides hot water only as it is needed.

6.2.3 Semi-Conditioned/Tropical Homes

6.2.3.1 Tropical Zone Requirements

Amend IECC Section R401.2.1 to read as follows:

R401.2.1 Tropical zone. Residential buildings in the tropical zone at elevations below 2,400 feet (731.5 m) above sea level shall be deemed to comply with this chapter where the following conditions are met:

1. Not more than one-half of the ~~occupied space~~ dwelling unit is air conditioned.
2. The ~~occupied space~~ dwelling unit is not heated.
3. Solar, wind or other renewable energy source supplies not less than ~~80~~ 90 percent of the energy for service water heating.
4. Glazing in dwelling units ~~conditioned space has~~ shall have a maximum a solar heat gain coefficient as specified in Table R402.2.1. ~~of less than or equal to 0.40, or has an overhang with a projection factor equal to or greater than 0.30.~~

Table R402.2.1. Window SHGC Requirements

<u>Projection Factor of overhang from base of average window sill^b</u>	<u>SHGC</u>
<u>< .30</u>	<u>.25</u>
<u>.30 - .50</u>	<u>.40</u>
<u>≥.50</u>	<u>N/A</u>

^bException: North-facing windows with pf > .20 are exempt from the SHGC requirement.

Overhangs shall extend 2 feet on each side of window or to nearest wall, whichever is less.

5. Skylights in dwelling units shall have a maximum U-factor as specified in Table R402.1.2.

56. Permanently installed lighting is in accordance with Section R404.

67. ~~The exterior roof surface~~ roof/ceiling complies with one of the following options:

1. Comply with one of the roof surface options in Table C402.3 and install R-13 insulation or greater.

2. Install R-19 insulation or greater.

~~in Table C402.3 or the roof/ceiling has insulation with an R-value of R-15 greater~~

If present, attics above the insulation are vented and attics below the insulation are unvented.

Exception: The roof/ceiling assembly are permitted to comply with Section R407.

78. Roof surfaces have a minimum slope of ¼ inch per foot of run. The finished roof does not have water accumulation areas.

89. Operable fenestration provides ventilation area equal to not less than 14 percent of the floor area in each room.

Alternatively, equivalent ventilation is provided by a ventilation fan.

910. Bedrooms with exterior walls facing two different direction have operable fenestration or exterior walls facing two different directions.

1011. Interior doors to bedrooms are capable of being secured in the open position.

1112. A ceiling fan or ceiling fan rough-in is provided for bedrooms and the largest space that is not used as bedroom.

13. Jalousie windows shall have an air infiltration rate of no more than 1.2 cfm per square foot (6.1 L/s/m²).

14. Walls, floors and ceilings separating air conditioned spaces from non-air conditioned spaces shall be constructed to limit air leakage in accordance with the requirements in Table R402.4.1.1.

Discussion: Changes were proposed to the Tropical Zone requirements to correct wording from the 2015 IECC, to bring in flexibility to the code and to add state amendments to bring the code in line with current state requirements.

Occupied space is changed to dwelling unit because occupied space includes all buildings within a project, e.g., an unconditioned garage that would be considered out of the scope of this code provision. Dwelling unit is a more appropriate term.

Solar systems per HRS 196-6.5 are specified to be consistent with state legislation (see Section 6.2.2.3).

An SHGC projection factor trade-off is provided for the vertical fenestration SHGC to account for the shading effects of overhangs. This provides an energy neutral trade-off.

No thermal or SHGC requirements for skylights were included in Tropical Zone requirements. The skylight provision addition provides a link to the prescriptive requirements in the 2015 IECC. Installing lower SHGC skylights will reduce the cooling load in the space and will increase occupant comfort.

R-13 roof/ceiling insulation with the addition of a cool roof membrane or R-19 insulation only performs equally based on analysis. See Section 6.2.4.3 for additional information.

Increasing the thermal efficiency in the attic for a Tropical Zone house will increase thermal comfort to the occupant and, with the use of ceiling fans, will eliminate the need for installing cooling systems in the house. A Points trade-off approach (see section 6.2.4 for details) provides the ability to trade-off efficiencies in the roof for increased efficiencies in other parts of the house for an energy neutral trade-off.

Increased air infiltration rates are proposed for Jalousie windows for Tropical Zone houses. These windows aid cross ventilation which eliminates the need for air conditioning in semi-heated houses. Jalousie windows cannot meet the current air infiltration rate of 0.3 cfm/ft² currently in the 2015 IECC.

Air sealing between the air conditioned space and non-air conditioned space is important to keep the space conditioning in the areas where it was intended. Sealing up assemblies between the two spaces will also reduce the possibility of moisture issues within the framed cavities.

Analysis and Recommendation: The 2015 IECC includes provisions for naturally ventilated and semi-conditioned/multi-mode spaces in Section R401.2.1. The naturally ventilated and semi-conditioned spaces assume ceiling fans installed in living areas and bedrooms, as required for unconditioned space. The cooling effect of circulating fans can be substantial. An air speed of roughly 3.3 ft/s is capable of offsetting a 5.4°F increase in indoor temperature, while an air speed of 9.84 ft/s has a cooling effect of roughly 12.6°F.²³ The 2015 HEC will apply all roof and wall assembly provisions of the IECC to multi-mode and naturally ventilated homes. The goal of modeling this amendment was to answer two important questions:

- Will the multi-mode homes decrease energy use over fully-conditioned homes?
- Will interior temperatures in naturally ventilated homes provide adequate comfort and eliminate the need for air-conditioning?

³⁵ *The Revenge of the Circulating Fan. Low-Tech Magazine.* (2014). 7 Dec. 2014.
<http://www.lowtechmagazine.com/2014/09/circulating-fans-air-conditioning.html#more>

Evaluating a series of permutations shows that multi-mode homes (50% air conditioned), as illustrated in Table 10, decrease energy use by 9-13% over fully-conditioned homes. Air from the conditioned and non-conditioned spaces mix and without significant air sealing to separate the two spaces, the mechanical equipment can be expected to compensate until the non-conditioned space is partially cooled.

Each amendment was evaluated on both steel frame and wood frame homes, evaluating thermal comfort in unconditioned homes. Ceiling fans and jalousie windows were assumed, and in each case, the fully optimized prototype has R-13 wall insulation, 90% high efficacy lighting, R-30 ceiling, radiant barrier and cool roof, and 1.5 cfm/ft² of solar-powered attic ventilation.

Figure 10 illustrates the adaptive thermal comfort analysis. If the occupant is allowed to adjust their body temperature, the comfort range increases parallel to outdoor temperatures. The figure includes two bands illustrating a 90% and 80% acceptable rate. The comfort bands do not change based on the efficiency measures modeled, but are used as a baseline to determine the total number of hours that the occupant is uncomfortable if the efficiency measure is installed in a building. If the 90% criteria (more stringent) is used, there is more time (1237 hours) above the 90% upper limit. 1237 hours is about 14% of annual hours. If 80% (less stringent) is used as the benchmark, the number drops below 487 hours a year, or 5.5%. The impact that the efficiency measure has on the building is based on the number of hours above the comfort band.

The effect of ceiling fans is not accounted for in the adaptive thermal comfort analysis and can have a positive effect on the comfort of the occupant. Ceiling fans result in a perceived cooling effect of 5.4°F to 12.6°F based on fan speed (air speed of approximately 3.3 ft/s to 9.84 ft/s respectively). Ninety percent of the occupants will be comfortable using ceiling fans operating at low fan speeds (3.3 ft/s) up to a monthly outdoor average outside air temperature of 79°F (see Figure 10). When the monthly average outside air temperature exceeds 79°F, 90% of the occupants will be comfortable using a fan operating at higher speeds (9.84 ft/s).

Figure 10. Adaptive Thermal Comfort, Optimized Wood Frame 2015 HEC

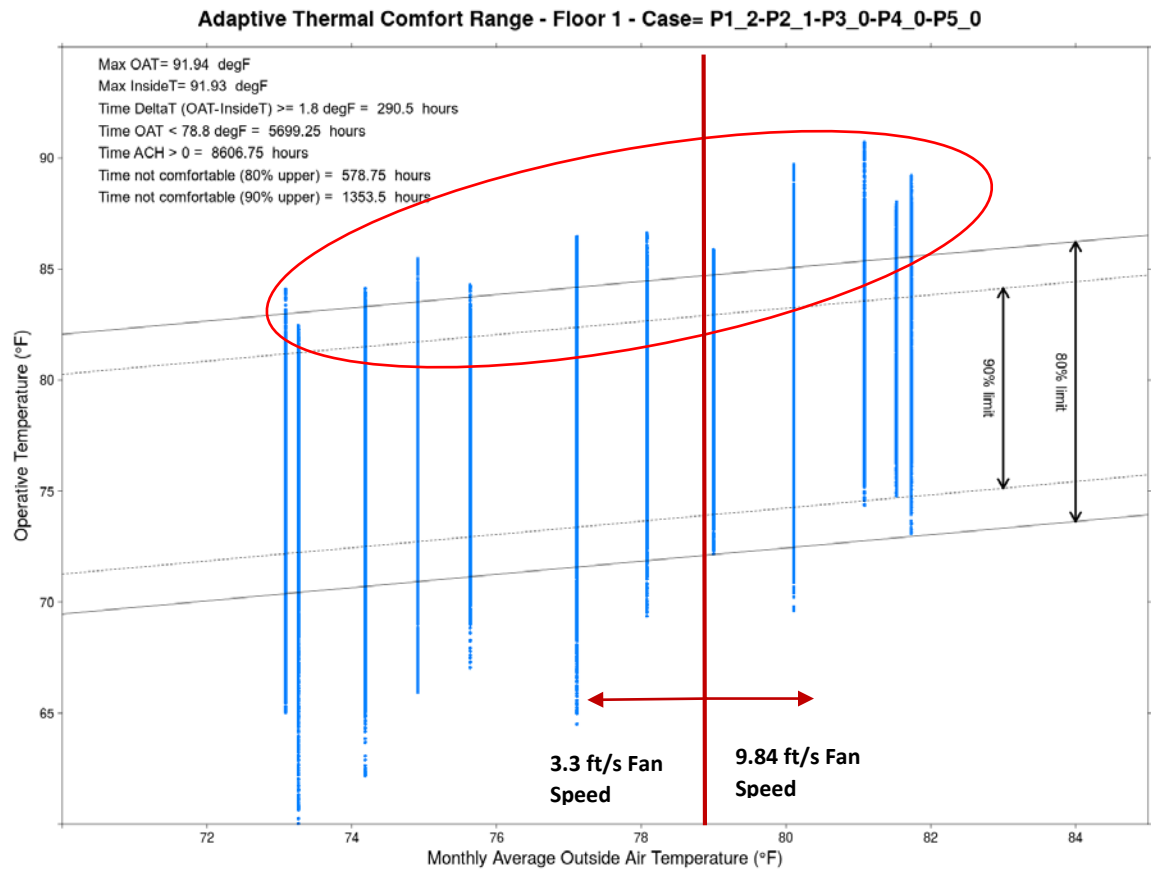


Table 6 below illustrates that there is minimal time throughout the year when indoor temperatures are outside of the comfort zone, allowing for natural ventilation and the avoidance of energy use through mechanical cooling.

Table 6. Percentage of Hours Above Indoor 80% Comfort Level

	Steel Frame	Wood Frame
	2015 HEC	2015 HEC
Naturally Ventilated 2015 IECC	5.8%	5.8%
Naturally Ventilated, Optimized 2015 HEC	5.5%	5.5%

The consultant recommends amendment 6.2.2.1, applying the SBCC approved 2009 amendment extending Section 101.5.2 of the 2015 IECC to unconditioned, habitable spaces. The consultant further recommends air sealing requirements between conditioned and non-conditioned spaces.

6.2.3.2 Fenestration Shading Options

Amend Section R402.3.2 of the IECC to read as follows:

R402.3.2 Glazed fenestration SHGC. Fenestration shall have a maximum *solar heat gain coefficient* as specified in Table R402.1.2. An area-weighted average of fenestration products more than 50-percent glazed shall be permitted to satisfy the SHGC requirements.

Dynamic glazing shall be permitted to satisfy the SHGC requirements of Table R402.1.2 provided the ratio of the higher to lower labeled SHGC is greater than the or equal to 2.4 and the dynamic glazing is automatically controlled to modulate the amount of solar gain into the space in multiple steps. Dynamic glazing shall be considered separately from other fenestration, and area-weighted averaging with other fenestration that is not dynamic glazing shall not be permitted.

Exception: *Dynamic glazing* is not required to comply with this section when both the lower and higher labeled SHGC already comply with the requirements of Table R402.1.1.

Discussion: The added language links the allowance for an area weighted average SHGC with the specific SHGC requirement in Section R402.3.2. This change will clarify the requirement. Additionally, on homes with outdoor shading and lanai areas, the lower SHGC is not necessary. This provides an alternative for window selection whether jalousie, slider or casement style.

Analysis and Recommendation: No modeling was conducted as shaded windows do not require increased SHGC. The consultant recommends the HEC be amended to include flexible SHGC levels in shaded windows.

6.2.3.3 *Air Leakage Allowance*

Apply Hawaii's 2009 amendment for 1.2 cfm/ft² air leakage allowance of jalousie windows to Section R402.4.3.

Discussion: Jalousie windows are a popular choice of windows in Hawaii and other tropical climates as they allow maximum airflow for natural ventilation. Jalousie windows are made like glass shutters and consist of parallel slats, or louvers, set in a frame. The slatted design allows almost the entire area of the window to open from top to bottom, making them ideal for homes with little to no air-conditioning that rely on natural ventilation for air circulation and cooling. When open, the windows utilize trade winds to cool homes when the weather is mild which allows air-conditioning to be left off. Jalousie windows can also remain open in the rain as the slanted design keeps the majority of the rain from coming inside the home.

The design of the jalousie makes them harder to seal, however. Even when closed, air penetrates through the slats and along the hinges of the window. As recommended in the Hawaii Homeowner's Guide to Energy, Comfort and Value, jalousies should be avoided if the home will be air-conditioned.²⁴ Further research states that jalousie windows lead to an increased demand in energy due to air-conditioning during hot weather conditions.²⁵

The higher air leakage allowance achieved by the 2009 SBCC approved amendment is necessary to maintain the use of jalousie windows throughout Hawaii.

²⁴ "Hawaii Homeowner's Guide"

²⁵ Kolderup Consulting, Stringency Assessment

Analysis and Recommendation: Multi-mode homes were assumed to have jalousie windows installed and analysis was run using the associated higher leakage rates. As illustrated in Table 7, multi-mode homes with jalousie windows were considerably more efficient than the 2006 HEC base model.

The consultant recommends air leakage allowance as proposed for jalousie windows in Section 6.2.2.3.

Table 7. Multi-mode Residential Increased Air Leakage from Jalousie Windows, Compared to 2006 HEC 24.61 kBtu/ft²

	2015 IECC Base without Jalousie Windows	2015 IECC With Jalousie Windows
Wood frame Multi - Mode	20.38	20.63

6.2.4 Points-Based Options

6.2.4.1 Points-Based Options for Prescriptive Approach and Tropical Homes

Section R407 is added to the IECC to read as follows:

SECTION R407

POINTS OPTION

R407.1 General (Prescriptive). Above-grade walls and roofs are permitted to comply with the points option as an alternative to complying with Section R401.2.1 and R402.2.

R407.2 Requirements. One or more efficiency measures shall be selected for roof and above-grade wall systems from Table R407.1 that cumulatively equal or exceed 0 (zero) points.

As an alternative, above-grade walls and roofs are permitted to comply separately by scoring 0 (zero) or greater.

Discussion: The Points Option provides energy neutral trade-offs for different building assembly types. A prescriptive format was selected to increase the usability of the compliance approach. Energy analysis and research was done to determine the point allowances for each feature. All of the features are given +/- 1 point with the exception of high efficiency cooling equipment which is either given one (1) or two (2) points based on the SEER rating. The options that are included in the code reflect trade-offs from earlier versions of the Hawaii code, e.g., eliminating continuous insulation for metal framed walls by using reflective paint or high SEER cooling equipment as a trade-off for continuous insulation.

The goal of the points-based option is to score a "0" or greater for the wall and roof assembly types. Each of the options indicated in Table 11 is worth approximately 1% energy increase or decrease and is based on the analysis performed for other options discussed in Section 6.0.

Point options are fewer for naturally ventilated homes as the Tropical Zone already requires certain cooling related features.

TABLE R407.1
POINTS OPTION

<u>Walls</u>		<u>Standard Home Points</u>	<u>Tropical Home Points</u>
<u>Wood Framed</u>			
	<u>R-13 Cavity Wall Insulation</u>	<u>0</u>	<u>1</u>
	<u>R-19 Roof Insulation</u>	<u>-1</u>	<u>0</u>
	<u>R-19 Roof Insulation + Cool roof membrane¹ or Radiant Barrier³</u>	<u>0</u>	<u>1</u>
	<u>R-19 Roof Insulation + Attic Venting²</u>	<u>0</u>	<u>1</u>
	<u>R-30 Roof Insulation</u>	<u>0</u>	<u>1</u>
	<u>R-13 Wall Insulation + high reflectance walls⁴</u>	<u>1</u>	<u>2</u>
	<u>R-13 Wall insulation + 90% high efficacy lighting and Energy Star Appliances⁵</u>	<u>1</u>	<u>2</u>
	<u>R-13 Wall Insulation + exterior shading wpf=0.3⁶</u>	<u>1</u>	<u>2</u>
	<u>Ductless Air Conditioner⁷</u>	<u>1</u>	<u>1</u>
	<u>1.071 X Federal Minimum SEER for Air Conditioner</u>	<u>1</u>	<u>1</u>
	<u>1.142 X Federal Minimum SEER for Air Conditioner</u>	<u>2</u>	<u>2</u>
	<u>No air conditioning installed</u>	<u>Not Applicable</u>	<u>2</u>
	<u>House floor area ≤ 1,000 ft²</u>	<u>1</u>	<u>1</u>
	<u>House floor area ≥ 2,500 ft²</u>	<u>-1</u>	<u>-1</u>
	<u>Energy Star Fans⁸</u>	<u>1</u>	<u>1</u>
	<u>Install 1 kW or greater of solar electric</u>	<u>1</u>	<u>1</u>
<u>Metal Framed</u>			
	<u>R-13 +R 3 Wall Insulation</u>	<u>0</u>	<u>1</u>
	<u>R-13 cavity Wall insulation + R-0</u>	<u>-1</u>	<u>0</u>
	<u>R-13 Wall Insulation + high reflectance walls⁴</u>	<u>0</u>	<u>1</u>
	<u>R-13 wall insulation + 90% high efficacy lighting and Energy Star Appliances⁵</u>	<u>1</u>	<u>2</u>
	<u>R-13 Wall Insulation + exterior shading wpf=0.3⁶</u>	<u>0</u>	<u>1</u>
	<u>R-30 Roof Insulation</u>	<u>0</u>	<u>1</u>
	<u>R-19 Roof Insulation</u>	<u>-1</u>	<u>0</u>
	<u>R-19 + Cool roof membrane¹ or Radiant Barrier³</u>	<u>0</u>	<u>1</u>
	<u>R-19 Roof Insulation + Attic Venting²</u>	<u>0</u>	<u>1</u>
	<u>Ductless Air Conditioner⁷</u>	<u>1</u>	<u>1</u>
	<u>1.071 X Federal Minimum SEER for Air Conditioner</u>	<u>1</u>	<u>1</u>

	<u>1.142 X Federal Minimum SEER for Air Conditioner</u>	<u>2</u>	<u>2</u>
	<u>No air conditioning installed</u>	<u>Not Applicable</u>	<u>2</u>
	<u>House floor area ≤ 1,000 ft²</u>	<u>1</u>	<u>1</u>
	<u>House floor area ≥ 2,500 ft²</u>	<u>-1</u>	<u>-1</u>
	<u>Energy Star Fans⁷</u>	<u>1</u>	<u>1</u>
	<u>Install 1 kW or greater of solar electric</u>	<u>1</u>	<u>1</u>

¹ Cool roof with three-year aged solar reflectance of 0.55 and 3-year aged thermal emittance of 0.75 or 3-year aged solar reflectance index of 64.

² One cfm/ft² attic venting.

³ Radiant barrier shall have an emissivity of no greater than 0.05 as tested in accordance with ASTM E-408. The radiant barrier shall be installed in accordance with the manufacturer's installation instructions.

⁴ Walls with covering with a reflectance of ≥ 0.64.

⁵ Energy Star rated appliances include refrigerators, dishwashers, and clothes washers and must be installed for the Certificate of Occupancy

⁶ The wall projection factor is equal to the horizontal distance from the surface of the wall to the farthest most point of the overhang divided by the vertical distance from the first floor level to the bottom most point of the overhang.

⁷ All air conditioning systems in the house must be ductless to qualify for this credit.

⁸ Install ceiling fans in all bedrooms and the largest space that is not used as a bedroom.

Discussion. A points-based approach is consistent with Washington and Oregon residential energy codes that require the code user to select additional efficiency features including high efficiency heating and cooling systems, more efficient building envelope features, solar water heating and high efficacy lighting. However, in this case, the points option will only be used for envelope trade-offs. Due to Hawaii's cooling only climate and mandatory solar water heating requirements, many of the options that were included in Washington and Oregon were not included for Hawaii, such as the option for water source heat pumps, solar water heating, and high efficiency heating systems.

Non-compliant features were assigned a negative point total to allow the designer/builder to select an option with a positive point total to total "0" points. For example, steel framed walls with R-13 cavity insulation and no continuous insulation receive one negative point (-1). Features that were considered energy equivalent or more efficient than base code requirements were assigned one positive point (+1).

Analysis and Recommendations. The code was reviewed to determine the optimum placement for a points-based option. The exceptions already included in the current prescriptive approach provided the best opportunity to provide additional flexibility. The percent savings estimates used to assess positive or negative points was derived from the analysis used to determine energy savings for features outlined in Section 4.2. Each feature is worth a minimum of 1% energy increase (or decrease for features that do not meet the minimum prescriptive R-value requirements). While the current points concept is designed to be energy neutral, additional features can be added to the points table and the number of points required increased to gain additional efficiency from this option. The consultant recommends amendment 6.2.3, a points-based option for prescriptive approach and tropical homes. The following features included in Section 6.2.4.2 and 6.2.4.3 are included in the points-based option.

6.2.4.2 *Roof Ventilation*

Ventilation in attic assemblies via solar-powered exhaust fan that provides at least one cubic foot per minute of airflow for each square foot of roof area.

Discussion: Attic temperatures can exceed 160°F during hot summer days. Roof ventilation can reduce those temperatures by up to 50°F²⁶ and is a crucial component to keeping homes cool in Hawaii as radiant energy from the sun contributes to higher interior temperatures. Heat from the sun radiates onto roofing material and is transferred by conduction through the roof and into the attic air. If the hot air is allowed to remain inside the attic, heat will transfer into the home. Removing the hot air from an attic through roof ventilation minimizes the heat transfer process, resulting in lower interior temperatures and decreased cooling loads in both naturally and mechanically cooled spaces. The reduction of cooling loads leads to reduced energy consumption and increased cost savings. Additionally, attic ventilation extends the life of a roof. Heat from the sun causes the roof underlayment to become brittle and ineffective, requiring more frequent repairs and replacement.²⁷

Roof ventilation can be achieved through natural (passive) draft air convection, such as a baffled ridge vent, through forced (active) draft air convection, such as a solar-powered exhaust fan, or through a combination of the two. The IRC requires passive ventilation, at a minimum.

Active ventilation is more effective and appropriate for the Hawaiian climate. Solar-powered exhaust fans use photovoltaic panels to convert sunlight into electrical power and work by producing an active draft that replaces heated attic air with air outside of the home, as illustrated in Figure 11. Fresh air enters the attic through an air inlet area and exhausts the hot air that is inside. A properly sized solar attic ventilation system will reduce attic temperature to 5-10°F above the outdoor temperature.²⁸

²⁶ "Solar Attic Fans." *AlternateEnergy*. 1 Nov. 2014. <<http://www.alternateenergyhawaii.com/solar-attic-fans>>.

²⁷ Queensland Government Department of Public Works. "Designing for Queensland's Climate." 1 Nov. 2014. <<http://www.hpw.qld.gov.au/SiteCollectionDocuments/SmartDesignQldClimate.pdf>>.

²⁸ "Solar Attic Fan Information." *Solar Attic Fan Info*. Web. 1 Nov. 2014. <<http://www.solar-attic-fan-info.com/solar-attic-fan-information.php>>.

Figure 11. Solar-Powered Attic Fan

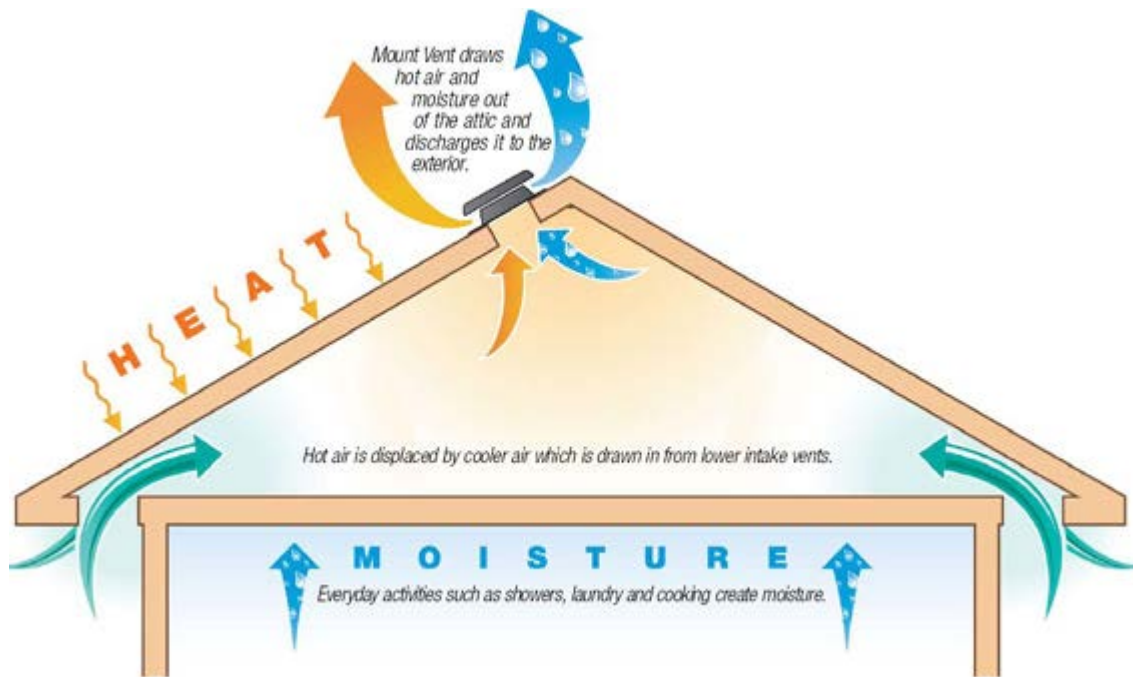


Photo Courtesy of Solar Attic Fan Info

Research shows that solar-attic fans provide a number of benefits, including:

- Operates during the day when direct sunlight is the greatest and attic requires greatest air circulation
- Removes moisture caused by every day activities such as showering and cooking
- Prevents moisture issues such as mold and mildew growth
- Environmentally friendly
- Zero operating cost²⁹

Additionally, a typical solar-attic fan installation will pay for itself in savings within 1-2 years of use.³⁰

Modeling Analysis and Recommendation: Modeling and research indicate the value of active attic ventilation. Minimum attic ventilation requirements under the International Residential Code is a net free ventilation area equivalent to $\frac{1}{150}$ of the area of the vented attic. Modeling did not indicate marked decrease in energy use due to attic ventilation between 0.5 and 1.5 cfm/ft², as shown in Table 8. Conditioned and multi-mode buildings with steel and wood framed walls were modeled with different attic ventilation rates. Their energy use can be compared to a building that complies with the 2006 HEC (24.61 kBut/ft²).

²⁹ "Solar Attic Fans Frequently Asked Questions." *Hawaii Solar Fans*. 1 Nov. 2014. <<http://www.hawaiisolarfans.com/FAQ/faq.aspx>>.

³⁰ "Solar Attic Fan Frequently Asked Questions." *Solar Attic Fan Info*. 1 Nov. 2014. <<http://www.solar-attic-fan-info.com/solar-attic-fan-faqs.php>>.

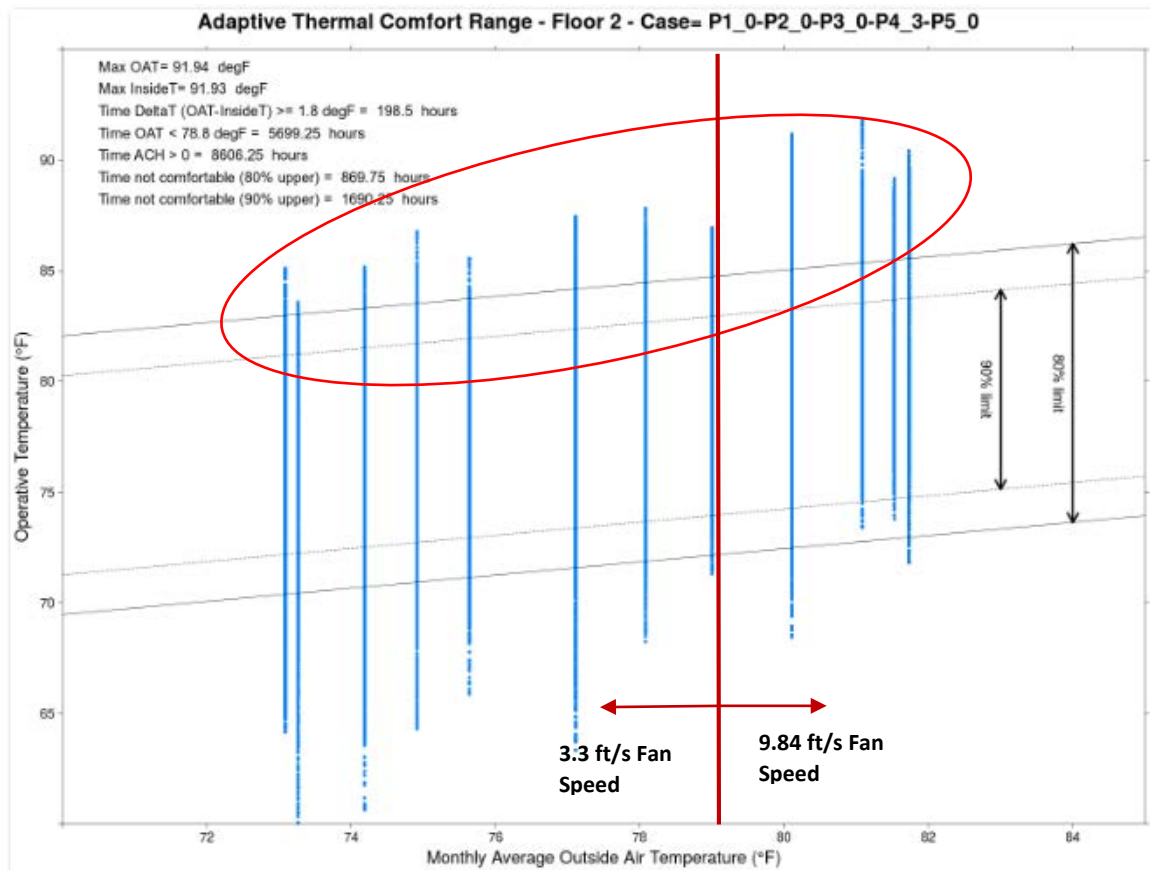
Table 8. Increased Ventilation Rates Compared to 2006 HEC 24.61 kBtu/ft²

	Proposed, Based on 2015 IECC		
	0.5 cfm/ft ²	1 cfm/ft ²	1.5 cfm/ft ²
Steel frame Conditioned	22.50	22.42	22.23
Steel frame Multi - Mode	19.51	19.45	19.43
Wood frame Conditioned	22.50	22.43	22.39
Wood frame Multi - Mode	20.20	20.14	20.12

Figure 12 illustrates the adaptive thermal comfort analysis for the second floor of a naturally ventilated home with attic ventilation increased to 1.5 cfm/ft². When the occupant is allowed to adjust their body temperature, the comfort range increases parallel to outdoor temperatures. Figure 12 includes two bands illustrating a 90% and 80% acceptable thermal comfort rate. The 80% band means that 80% of the people will be comfortable with the indoor temperature given the average (mean) monthly outside temperature. The 90% band indicates satisfaction with the indoor design temperature for 90% of the people. The comfort bands do not change based on the efficiency measures modeled but are used as a baseline to determine the total number of hours that the occupant is uncomfortable if the efficiency measure is installed in a building. If the 90% criteria (more stringent) is used, there is more time (1690 hours or roughly 19% of annual hours) in which occupants are not comfortable. If 80% (less stringent) is used as the benchmark, the number of hours occupants are uncomfortable drops below 870 hours per year, or 10% of annual hours. The impact that the efficiency measure has on the building is based on the number of hours above the comfort band.

The effect of ceiling fans are not accounted for in the adaptive thermal comfort analysis and can have a positive effect on the comfort of the occupant. Ceiling fans result in a perceived cooling effect of 5.4°F to 12.6°F based on fan speed (air speed of approximately 3.3 ft/s to 9.84 ft/s respectively). Ninety percent of the occupants will be comfortable using ceiling fans operating at low fan speeds (3.3 ft/s) up to a monthly outdoor average outside air temperature of 79°F (see Figure 12). When the monthly average outside air temperature exceeds 79°F, 90% of the occupants will be comfortable using a fan operating at higher speeds (9.84 ft/s). Refer to Section 6.2.2.1. The consultant also recommends that attic ventilation at 1 cfm/ft² be included as a point option, as indicated in Table 8.

Figure 12. Adaptive Thermal Comfort, 2015 IECC with Increased Attic Ventilation



The consultant recommends that attic ventilation at 1 cfm/ft² using solar-attic fans be included as a point option, as indicated in Table 8.

6.2.4.3 Roof Insulation

Insulate roofs by one of the following three options: R-19 with cool roofs; R-19 with radiant barrier; or R-30 installed under roof deck or on the attic floor.

Discussion: The reduction of solar heat gain through the roof is a primary concern for Hawaii residences. Solar radiation on the roof can lead to significant indoor temperature rise. One of the most useful strategies to avoid this is to adequately insulate the roof and/or ceiling space. The intent of the proposed 2015 amendment is to achieve maximum benefits from insulation when used in conjunction with other roof cooling techniques, including cool roofs and radiant barriers, while also providing low cost insulation alternatives. Current building practices in Hawaii already include both cool roofs and radiant barriers.

A cool roof is a roof that has been designed to reduce heat gain by reflecting more sunlight and absorbing less heat than a standard roof. Standard or dark roofs can reach temperatures up to 69°F greater than the outside air temperature in the summer sun. A cool roof under the same conditions will only increase in temperature up to 9°F greater than the outside air temperature or

a reduction of 60°F.³¹ Anecdotal reports indicate roof membrane drops of greater than 70°F. Cool roofs save money by reducing the need for air-conditioning and extending the life of both cooling equipment and roofing material.

Cool roofs function on the principal of solar reflectance. Solar reflectance (SR) is the fraction of solar energy that is reflected by the roof and is rated on a scale from 0 to 1, where 1 is the most reflective or emissive. Roofing materials are typically rated for solar absorptance (SA). SA is a measure of the proportion of solar radiation a body absorbs and is calculated as 1 – solar reflectance. Roofing material with a higher SA will absorb more energy and reach a higher temperature than roofing material with a lower SA. Selecting a material with a naturally low absorptance, such as an off-white or white tin roof, or applying a reflective coating to the roof deck reduces heat gain into buildings.³²

Radiant barriers, however, function on the principal of inside emissivity. Radiant energy from the sun typically makes roofs hot and much of the heat travels by conduction through roofing materials to the underside of the roof. The underside of the roof then radiates its gained heat energy onto cooler attic surfaces, such as the attic floor and any air ducts. Radiant barriers work in conjunction with an air space to reduce radiant heat gain from the underside of the roof to the cooler surfaces in the attic and into the interior of the building. Radiant barriers are most useful under dark tin roofs.

An evaluation of the radiant barrier and cool roof modeling performed by Britt/Makela Group, Inc. and the New Building Institute in the Republic of the Fiji Islands (Fiji) suggests that the savings potential for radiant barriers and cool roofs depends on the type of roof system. In a metal or black roofing system with no air barrier between the roof and the indoor space, the savings from ‘interrupting’ heat transfer through the assembly is significant. However, in systems where the roof has a vented air barrier within the assembly, or some inherent reflectivity, the savings associated with radiant barriers or cool roof systems are not as significant. The baseline prototype used in the Fiji analysis showed moderate savings since the baseline metal roof surface was assumed to be reasonably reflective.

The analysis completed in Fiji found that for naturally ventilated buildings (primary schools and small residences), cool roofs and radiant barriers contributed to reduced indoor temperatures, which increased occupant comfort but did not directly save energy. The percent savings numbers (58% for primary schools and 38% for small residences) represent the reduction in the number of hours that the interior temperatures in the buildings were likely to exceed 85° F. These numbers should be considered as a relative impact, not as a prediction of interior temperature performance. The savings provided for the naturally ventilated buildings include **both** a radiant barrier and a cool roof installation.

Other studies of reflective insulation effects tend to demonstrate more significant impacts than the Fiji modeling indicated. Although some of these studies may be overly optimistic due to

³¹ Ronnen Levinson. Cool Roof Q & A (draft). *Lawrence Berkeley National Laboratory*. (2009). 29 Jul. 2009. <http://coolcolors.lbl.gov/assets/docs/fact-sheets/Cool-roof-Q%2BA.pdf>.

³² Britt/Makela Group, Inc. "Fiji National Building Code Roof Systems Fact Sheet." (2014).

manufacturer involvement, the studies do tend to bolster the case for increased attention in the proposed use of radiant barriers and cool roofs.³³

Additionally, a study conducted by Britt/Makela Group, Inc. in the Commonwealth of the Northern Mariana Islands (CNMI) found that cool roofs installed on new construction are providing a noticeable difference in indoor air temperatures. Participants in the CNMI Department of Public Works recent cool roof rebate program reported indoor temperatures dropping up to 20 degrees and studies have shown typical cooling energy savings of 10-30% in cooling energy when using cool roofs.

Research was also conducted by Koldrup Consulting on the impact of the Hawaii amendments to the 2009 IECC for residential roof insulation that were approved by the SBCC but never codified. The addition of Section 402.1.6 provided four options for ceiling heat-gain reduction: insulation, radiant barrier plus ventilation, radiant barrier plus cool roof, or a roof heat gain factor calculation. The intent of the 2009 HI amendment was to provide potentially lower-cost paths to equal performance. An evaluation of the impact of the Hawaii Code amendment for residential roof insulation showed that the first option of R-30 insulation was essentially equal to the 2009 IECC baseline. Options 2, 3 and 4 were found to be less stringent than the 2009 IECC baseline requirement, resulting in an increase in electricity consumption of 4.3%, 1.8% and 3.1% respectively.³⁴

Furthermore, studies in other tropic and semi-tropic environments have identified roof insulation as a design element that is fundamental to tropical climates.³⁵ These studies suggest to:

- Install the highest affordable R-value
- Ensure that the selected insulation type has a reflective layer (such as reflective foil)
- Choose an insulation with both a reflective and thermal component
- Use light colors for external surfaces
- Avoid compressing insulation
- Consider encapsulated products if choosing fiberglass insulation to reduce the chance of contact with fibers
- As an alternative to fiberglass, consider blown-in insulation made from recycled paper and treated with fire and pest retardant

³³ Britt/Makela Group, Inc. and New Buildings Institute. "Incorporation of Energy Efficiency into the National Building Code: Final Report and Recommendations to the Ministries of the Fijian Government." (2014).

³⁴ Kolderup Consulting, Stringency Assessment

³⁵ Karol E Lai. Climatic Design and Changing Social Needs in the Tropics: A Case Study in Kuching, Sarawak. *Sustainability*. (2014). 1 Nov. 2014. <<http://www.mdpi.com/2071-1050/6/9/6278>>.

- Install a white roof to keep the roof surface up to 60°F cooler. ^{[25][36] [37] [38]}

For resource efficiency, the Hawaii Homeowner's Guide to Energy, Comfort and Value suggests using cellulose insulation as it is made in Hawaii from recycled paper and telephone books. Cellulose insulation can be wet-sprayed or blown into an enclosed space in dry form. When wet-sprayed, it is an excellent air leakage barrier. When mixed with sodium borate or boric acid, cellulose insulation is also an excellent fire retardant and pest control. ³⁹

Analysis and Recommendation: Since cool roofs work on the principal of solar reflectance and radiant barriers work on the principal of emissivity, the two may be combined to further decrease energy use. Figure 13 includes two bands illustrating a 90% and 80% acceptable thermal comfort rate. The comfort bands do not change based on the efficiency measures modeled, but are used as a baseline to determine the total number of hours that the occupant is uncomfortable if the efficiency measure is installed in a building. If the 80% (less stringent) is used as the benchmark, the number of hours occupants are uncomfortable drops below 870 hours a year, or 10% of annual hours. The impact that the efficiency measure has on the building is based on the number of hours above the comfort band.

The effect of ceiling fans are not accounted for in the adaptive thermal comfort analysis and can have a positive effect on the comfort of the occupant. Ceiling fans result in a perceived cooling effect of 5.4°F to 12.6°F based on fan speed (air speed of approximately 3.3 ft/s to 9.84 ft/s respectively). Ninety percent of the occupants will be comfortable using ceiling fans operating at low fan speeds (3.3 ft/s) up to a monthly outdoor average outside air temperature of 79°F (See Figure 13). When the monthly average outside air temperature exceeds 79°F, 90% of the occupants will be comfortable using a fan operating at higher speeds (9.84 ft/s). Refer to Section 6.2.3.1.

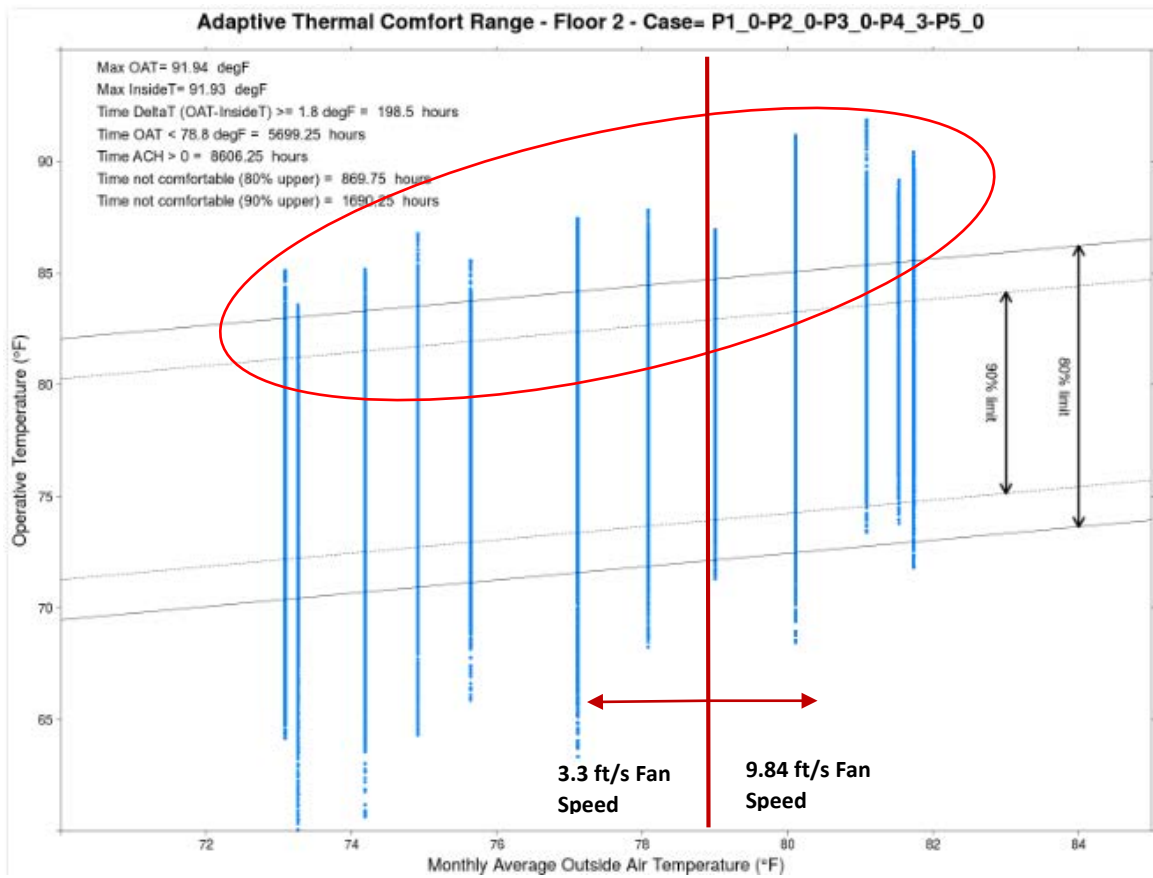
³⁶ McCathie, Sandy. "Hot Tips for Cool Homes in the Tropics: Passive Design Techniques to Reduce Reliance on Air-conditioning and Create a Cool and Comfortable Home in the Tropics." (2007). EcoSAVVY. 1 Nov. 2014. <<http://www.ecosavvy.com.au/assets/files/HotTipsForCoolHomesTropics.pdf>>.

³⁷ Kiatreungwattana, Kosol. "Building Efficiency in the Tropics." Low-Carbon Communities in the Caribbean Energy Workshop. National Renewable Energy Laboratory. 1 Mar. 2011. Lecture. <http://www.edinenergy.org/pdfs/lccc04_kiatreungwattana.pdf>.

³⁸ "Climate Responsive Building - Appropriate Building Construction in Tropical and Subtropical Regions." (1993). SKAT. 1 Nov. 2014. <<http://collections.infocollections.org/ukedu/en/d/JsK02ce/3.2.html>>.

³⁹ "Hawaii Homeowner's Guide to Energy, Comfort and Value." Department of Business, Economic Development and Tourism (2002). 1 Nov. 2014. <<http://energy.hawaii.gov/wp-content/uploads/2011/10/Hawaii-Homeowners-Guide.pdf>>.

Figure 13. Adaptive Thermal Comfort, 2015 IECC with Cool Roof and Radiant Barrier



As indicated in Table 9, energy use can be reduced through multiple means of decreasing rooftop heat gain:

Table 9. Reducing Rooftop Heat Gain Compared to 2006 HEC 24.61 kBtu/ft²

	2015 Base R-30	Amended 2015 R-30 Roof Insulation			2015 Base R-19	Amended R-19 Roof Insulation		
		Radiant Barrier	Cool Roof	Cool Roof Plus Radiant		Radiant Barrier	Cool Roof	Cool Roof Plus Radiant
Steel frame Conditioned	22.70	22.70	22.21	22.15	23.24	23.24	22.46	22.26
Steel frame Multi - Mode	19.64	19.64	19.29	19.25	20.57	20.57	19.73	19.38
Wood frame Conditioned	22.73	22.73	22.31	22.25	23.07	23.07	22.46	22.35
Wood frame Multi - Mode	20.39	20.39	20.03	19.99	20.86	20.86	20.25	20.10

The analysis indicates that the 2006 HEC, as well as the approved 2009 amendment language (Figure 14), Section 402.1.2, Table 402.1.6.1 Design Options 1 (R-19/R-30) and 3 (cool roofs plus radiant barrier) can be effective. The Consultant recommends that both cool roofs and radiant barriers be included as point options as indicated in Table 9.

Figure 14. SBCC Approved Table 402.1.6.1 Design Options, Amendment to the 2009 IECC

**Table [402.1.1.1] 402.1.6.1
Ceiling Insulation for Buildings in Climate Zone 1**

Design Option	Design and Construction Components				
	Roof Insulation (Section [402.1.1.4] 402.1.6.4)	Attic Ventilation (Section [402.1.1.5] 402.1.6.5)	Radiant Barrier (Section [402.1.1.6] 402.1.6.6)	Cool Roof (Section [402.1.1.7] 402.1.6.7)	Roof Heat Gain Factor below 0.05 (Section [402.1.1.8] 402.1.6.8)
1	R ¹				
[2 ^a] 2		R	R		
[3 ^a] 3			R	R	
[4 ^a] 4					R

¹ Required

6.2.5 Performance Compliance Option

6.2.5.1 Simulate Performance Alternative

Amend IECC Table R405.5.2(1) to read as follows:

Table R405.5.2(1) SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS		
BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Heating Systems	<p>As proposed for other than electric heating without without a heat pump, where the proposed design utilizes electric heating without a heat pump the standard reference design shall be an air source heat pump meeting the requirements of section C403 of the ICC Commercial Provisions.</p> <p><u>Fuel type: same as proposed design</u></p> <p><u>Efficiencies:</u></p> <p><u>Electric: Air-source heat pump with prevailing federal minimum standards</u></p> <p><u>Nonelectric furnaces: natural gas furnace with prevailing federal minimum standards</u></p> <p><u>Nonelectric boilers: natural gas boiler with prevailing federal minimum standards</u></p> <p>Capacity: sized in accordance with Section R403.7</p>	<p>As proposed</p> <p>As proposed</p> <p>As proposed</p> <p>As proposed</p> <p>As proposed</p>
Cooling systems	As proposed	

	<u>Fuel type: Electric</u> <u>Efficiency: in accordance with prevailing federal minimum standards</u> Capacity: sized in accordance with Section R403.7	As proposed As proposed
Service water heating	As proposed <u>Fuel type: same as proposed design</u> <u>Efficiency: in accordance with prevailing federal minimum standards</u> Use: Same as proposed design	As proposed <u>As proposed</u> <u>gal/day = 30+(10x Nbr)</u>

Discussion: Energy neutral trade-offs are proposed by including the ability to trade-off high efficiency heating, cooling and water heating system efficiencies with building envelope features.

6.2.6 Existing Building Requirements

6.2.6.1 Compliance

Amend Section R501.4 of the IECC to read as follows:

R501.4 Compliance. *Alterations, repairs, additions and changes of occupancy to, or relocation of, existing buildings and structures shall comply with the provisions and regulations for alterations, repairs, additions and changes of occupancy or relocation, as adopted by the authorities having jurisdiction. ~~respectively, in the International Residential Code, International Building Code, International Fire Code, International Fuel Gas Code, International Mechanical Code, International Plumbing Code, International Property Maintenance Code, International Private Sewage Disposal Code and NFPA 70.~~*

Discussion: The proposed amendment strikes language requiring existing building projects to comply with the suite of International codes when these codes may not have been adopted by the local jurisdiction. This amendment is consistent with Hawaii Revised Statutes 107-25.

6.2.6.2 Building Envelope

Amend Section R503.1.1 of the IECC to read as follows:

Roof without insulation in the cavity and where the sheathing or insulation is exposed during a roof replacement ~~reroofing~~ ~~shall be insulated either above or below the sheathing.~~ meet one of the following:

1. R-30 cavity insulation or the cool roof requirements in Section C402.3 for residential buildings.
2. R-19 cavity insulation or the cool roof requirements in Section C402.3 for Tropical Zone residential buildings.

Discussion: The proposed language clarifies roof replacement requirement in the code and provides the ability to meet the requirements by installing a cool roof as an option to installing additional roof ceiling insulation.

7 ESTIMATED IMPACTS: HEC AMENDED 2015 IECC vs. 2006 HEC AND 2015 IECC/ASHRAE 90.1-2013

7.1 COMMERCIAL ENERGY SAVINGS

7.1.1 Proposed 2015 HEC Amendments Compared to 2006 HEC

Adopting the base 2015 IECC with references to ASHRAE 90.1-2013 would save 35-40% energy over the 2006 HEC with references to ASHRAE 90.1-2004. The amendments being considered by the HSEO will further increase potential energy savings.

Estimated energy savings for three of the four potential commercial amendments were based on research: sub-metering, automated demand response and in-room energy management systems. As noted in Section 6, each amendment provided increased energy efficiency over the baseline code.

7.1.2 Proposed 2015 HEC Amendments Compared to ASHRAE 90.1-2013

Since the 2015 IECC references ASHRAE 90.1-2013, the HEC would meet or exceed ASHRAE 90.1-2013 unless the amendments were such that overall energy use increased.

As documented in Section 6, estimated energy savings for three of the four potential commercial amendments were based on research: sub-metering, automated demand response and in-room energy management systems. Each amendment was found to provide increased energy efficiency of the 2015 HEC compared to the 2015 IECC.

In addition, the final amendment for exterior wall insulation is shown to be at least as efficient as the base ASHRAE 90.1-2013.

7.2 RESIDENTIAL ENERGY SAVINGS

7.2.1 Proposed 2015 HEC Amendments Compared to 2006 HEC

Analyzing the permutations of amendments, the following table illustrates the options which provide the greatest potential energy savings for wood frame and steel frame construction. In each case, the fully optimized prototype (i.e., the prototype with efficiency features that, when combined, offer the greatest savings potential) includes R-13 wall insulation, 90% high efficacy lighting, R-30 ceiling, radiant barrier and cool roof and 1.5 cfm/ft² of solar-powered attic ventilation. The 2015 HEC shows significant savings in energy use when compared to the 2006 HEC for each case.

Table 10. Annual Potential Savings Compared to 2006 HEC

	2006 HEC Base Energy Use	Wood Frame		Steel Frame	
		2015 HEC	Potential Savings , % (2006 HEC Compared to 2015 HEC)	2015 HEC	Potential Savings, % (2006 HEC Compared to 2015 HEC)
Fully Conditioned, Base Case	59,059	55,337	6%	54,006	9%
Fully Conditioned, Optimized	59,059	51,374	13%	50,611	14%
Multi-Mode Base Case	59,059	49,459	16%	44,034	25%
Multi-Mode Optimized¹	59,059	46,438	21%	45,177	24%
Unconditioned Base Case	59,059	33,222	44%	33,222	44%
Unconditioned Optimized	59,059	30,921	48%	30,921	48%

¹ Optimized: The prototype with efficiency features that, when combined, offer the greatest savings potential.

7.2.2 Estimated Savings of the 2015 HEC Compared to the 2015 IECC

The base case 2015 HEC is the 2015 IECC without amendments and will have the same energy use as the 2015 IECC. The majority of amendments proposed for the 2015 HEC result in less energy use than the base case, as illustrated in Table 11.

Table 11. Proposed 2015 HEC Amendments Compared to 2015 IECC 22.73 kBtu/ft²

	Attic Ventilation			Amended 2015 R-30 Roof Insulation			Amended R-19 Roof Insulation			Amended Wall Insulation Reduced to R-13				Amended Fenestration Air Leakage
Base 2015 IECC: 22.73	0.5 cfm/ft ²	1.0 cfm/ft ²	1.5 cfm/ft ²	Radiant Barrier	Cool Roof	Cool Roof Plus Radiant Barrier	Radiant Barrier	Cool Roof	Cool Roof Plus Radiant Barrier	Exterior wall reflectance =0.64	90% high efficacy light	External shading PF=0.3	SEER 14	
	22.50	22.43	22.39	22.73	23.31	22.25	23.07	22.46	22.35	22.44	21.97	22.25	22.90	20.63

7.2.3 Residential Ceiling Fan and Air-Conditioning Systems Cost Estimate

Cost estimates were developed for the installation of ceiling fan and air-conditioning systems, including mini-split ductless and central ducted cooling systems, in a typical residential building. A house size of 2,000 ft² with 3 bedrooms was assumed for the cost estimate. Total peak cooling loads were determined using the REM/Design Software and the home was assumed to be in compliance with the 2015 IECC. The total peak cooling load was estimated at 19 kBtu. A 24 kBtu (2 ton) air conditioner was assumed for the cost estimates based on availability in Hawaii. Every effort was made to reflect regional costs in Hawaii for the development of the estimates.

Ceiling Fans. Installation cost estimates were developed for ceiling fans to meet the requirement of the Tropical Zone in the 2015 IECC (one fan per bedroom and one fan per largest living space in the house). Installed costs for low, medium and high cost ceiling fans were determined based on ceiling fans available at the Home Depot store in Honolulu. The total estimated installed costs for the purchase and installation of four fans ranged from a low of \$659.08 to a high of \$1,056.00 (see Table 12).

Table 12. Ceiling Fan Cost Estimate

Description	Cfm	Cost ¹	Number of Fans ²	Total Material Cost ³	Total Estimated Labor (hr) ⁴	Estimated Labor Cost	Total Estimated Labor	Total Estimated Installed Cost
Hunter 44 inch Holden New Bronze Ceiling Fan	3,346	\$99.77	4	\$399.08	4	\$65.00	\$260.00	\$659.08
Channing 52 inch Indoor Brushed Nickel Ceiling Fan	4,576	\$144.00	4	\$456.00	4	\$65.00	\$260.00	\$716.00
Grand Cayman 54 inch Onyx Bengal Damp Rated Ceiling Fan with Light Kit	6,100	\$199.00	4	\$796.00	4	\$65.00	\$260	\$1,056.00

¹ Fan prices from Home Depot in Honolulu

² Assume 3 bedroom house (3 fans) with one fan in the largest living space per the IECC Tropical Zone requirements

³ Estimated labor costs based on internet search - <http://www.topelectricians.com/estimates/rates>

⁴ Assume 1 hour of labor per ceiling fan for installation

Central Ducted Cooling System. An estimated cost to install a 24 kBtu (2 ton) central air-conditioning system was determined using the U.S. DOE's Building Component Cost Community (BC3) database. For the purposes of this estimate, a system is assumed to include the condensing unit, air handler and duct system. A range of costs were calculated based on available cost data

(see Table 13). A location multiplier, provided by the BC3 database, was used to adjust costs for regional differences. Estimated costs ranged from a low of \$3,659.54 (\$1,829.77/ton) to \$4,119.61 (\$2,059.81/ton).

Table 13. Central Ducted Cooling System Cost Estimate

Description	Unit cost ¹	Labor ²	Total Cost	Location Multiplier ³	Total Adjusted Cost
Low Cost	\$1,964.52	\$877.62	\$2,842.14	128.76	\$3,659.54
Medium Cost	\$2,082.94	\$877.62	\$2,960.56	128.76	\$3,812.02
High Cost	\$2,321.83	\$877.62	\$3,199.45	128.76	\$4,119.61

¹Unit Cost from the U.S. DOE BC3 database for a 36 kBtu capacity central air conditioner. Costs were prorated for a 24 kBtu air conditioner. Website:

[http://bc3.pnnl.gov/components/residential_components/Air%20conditioner%20-%20Air%20conditioning%20system/?f\[0\]=field_building_type%3AResidential](http://bc3.pnnl.gov/components/residential_components/Air%20conditioner%20-%20Air%20conditioning%20system/?f[0]=field_building_type%3AResidential)

²Labor costs from the U.S. DOE BC3 database. See footnote 1 for website address.

³ Location multiplier from the U.S. DOE BC3 database. The multiplier reflects cost adjustments for unit and labor costs on a state-by-state basis. Website: <http://bc3.pnnl.gov/location-factors>

Mini-Split Ductless Cooling Systems. An estimated cost to install mini-split ductless cooling systems (ductless systems) was determined using cost data from a Home Depot store in Hawaii and estimated labor costs based on online research. The estimate assumed that ductless systems were installed in each of the bedrooms in addition to one ductless system for the largest living space in the house for a total of four systems. The cost estimate also assumes that 12 kBtu (1 ton) ductless systems were installed in each room, exceeding the total cooling load of the house. The smallest capacity systems were selected based on availability from Home Depot. Assumptions for total labor costs are included in the footnotes in Table 14. The total estimated cost for the installation of four 1 ton systems is \$4,980 (\$1,245/ton).

Table 14. Ductless Mini-Split System Cost Estimate

Description	Unit Size (kBtu)	Cost ¹	Number of Units ²	Total Material Cost ³	Total Estimated Labor Cost ³	Estimated Labor Cost	Total Estimated Cost
Elegance Ductless Mini-Split A/C	12	\$798.00	4	\$3,192.00	\$447.00	\$1,788.00	\$4,980

¹ Estimate based on 2,000 ft² house with 3 bedrooms. Building envelope assumes compliance with the 2015 IECC for Climate Zone 1. Total cooling load using REM/Design is 19 kBtu/h. Cost based on Elegance 12,000 mini-split air-conditioning from Home Depot

² Assume 4 units per house. One for each bedroom and one unit for the largest living space

³ Labor Cost per unit based on homewyse website: http://www.homewyse.com/services/cost_to_install_air_conditioning.html

7.3 COSTS

Research indicates the HSEO proposed commercial amendments have proven cost effective, as noted below:

Sub-Metering. The requirement to install sub-metering at time of construction, as opposed to including it in a retrofit, is the most cost effective means of metering. This amendment is currently part of the 2006 HEC; extending sub-metering to the 2015 HEC will not generate additional costs.

Demand Response. Cost-benefit analysis of demand response systems indicates that Auto-DR systems will decrease energy use. Research also recognizes the need for the development of a protocol to consistently assess how much energy use will decrease and the cost benefits associated with a demand response system.⁴⁰ Inclusion of the demand response amendment in the 2015 HEC is dependent upon the local utility system and language for the final proposed amendment has not yet been developed. As such, the cost-benefit of such a utility wide program is beyond the scope of this report.

In-Room Energy Management Systems for Hotels/Motels and Condominiums. Research conducted for the California Energy Commission⁴¹ indicates an annual energy savings of approximately 180 kilowatt-hours (kWh) per year.⁴² Assuming an average cost of thirty cents per kWh,⁴³ the savings is estimated at \$54/year. At a cost of less than \$300/unit installation, the payback is less than six years. The same analysis showed the life cycle cost savings per guest room ranges from \$49 to \$203.

Wall Insulation Alternatives. The roof wall insulation options for mass and steel frame high rise residential provide an opportunity to minimize labor and material cost while maintaining or improving energy efficiency.

As noted by HSEO staff, residential Hawaii amendments have either a minimal cost premium or reduce the cost of construction. The roof and wall options each minimize labor and material cost while maintaining or improving energy efficiency. A Building Industry Association representative resides on the SBCC and has had an opportunity to vet all amendments for cost concerns.

⁴⁰ California Public Utilities Commission. "2010 Demand Response Cost Effectiveness Protocols." (2010). 1 Nov. 2014. <[http://www.cpuc.ca.gov/PUC/energy/Demand Response/Cost-Effectiveness.htm](http://www.cpuc.ca.gov/PUC/energy/Demand%20Response/Cost-Effectiveness.htm)>.

⁴¹ Stein, Window and Door Switches

⁴² Mid-range savings for California Climate Zones 6 and 8, most relevant to Hawaii.

⁴³ "Average Electricity Prices for Hawaiian Electric, Maui Electric, and Hawaii Electric Light Company." *Hawaiian Electric Light Company*. 1 Nov. 2014. <<http://www.heco.com/heco/Residential/Electric-Rates/Average-Electricity-Prices-for-Hawaiian-Electric,-Maui-Electric,-and-Hawaii-Electric-Light-Company>>.

8 ENERGY SAVINGS FORECAST FOR THE RESIDENTIAL AND COMMERCIAL PROVISIONS OF THE 2015 IECC

8.1 INTRODUCTION

The following report includes the construction and energy impact forecasts for residential and nonresidential projects in the years 2016, 2026, 2030 and 2036 based on the adoption of the 2015 International Energy Conservation Code (IECC) in the state of Hawaii with proposed amendments. Construction forecasts were completed using data from local building departments, Dodge data and construction starts collected previously by Kolderup Consulting.

The energy impact estimates compare the 2015 IECC to both the 2006 Hawaii Energy Code for residential buildings and to ASHRAE Standard 90.1-2004 for commercial buildings. The methodology used to determine the energy savings forecasts was based on the methodology and data used by Kolderup Consulting included in the report *Hawaii Building Energy Code Stringency Assessment and Savings Forecast*.⁴⁴

8.2 RESIDENTIAL CONSTRUCTION FORECAST

The forecast for residential construction is based on construction activity of the last 10 years (Table 15). Construction start data for 2005 to 2011 was based on Kolderup residential construction data derived from Dodge data. Estimated residential construction starts for 2012 to 2015 were based on building permit data from Oahu County. Permit activity was estimated for Hawaii, Kauai, Molokai and Lanai by extrapolating the Oahu permit data using population weighting for each island.

The data shows a ten-year average of 2,813 single-family homes per year and 1,420 apartment units per year (for multi-family buildings 3-stories and less). The data also shows a significant decline in construction since 2005 for both single-family and multi-family dwelling units which includes the years impacted by the recession.

⁴⁴ Kolderup Consulting. "Hawaii Building Energy Code Stringency Assessment and Savings Forecast." (2012). 1 Nov. 2014. <http://energy.hawaii.gov/wp-content/uploads/2011/10/Energy-Code-Stringency-Analysis_v5.pdf>.

Table 15. Residential Construction History – Number of Dwelling Units

Year	Single Family ^{1, 2}	Multi-family Units ^{1,2,3}
2005	6413	2490
2006	5191	1126
2007	4370	1342
2008	2653	987
2009	2145	381
2010	1702	1513
2011	1504	1100
2012 ²	1377	1403
2013	1565	2147
2014	1209	986
2015	1307	3217
5-yr Average	1471	1771
10-yr Average	2813	1420

¹ Dodge data provided by Mary Blewitt, Department of Business, Economic Development, and Tourism

² Cumulative building permit data from 2012 to 2015 estimated based on Oahu Building Permit data

³ Multi-family data is for buildings 3-story and less in height

The residential construction forecast used in this analysis is illustrated in Figure 15 and Figure 16. The construction activity for 2016 is assumed to be equal to the 5-year average, which is 1,471 single-family units per year and 1,771 apartment units per year. For single-family dwelling units, the activity is assumed to increase until 2018 when it would reach the 10-year average. For multi-family units, the activity is assumed to decrease until 2018 when it would reach the 10-year average (Kolderup).

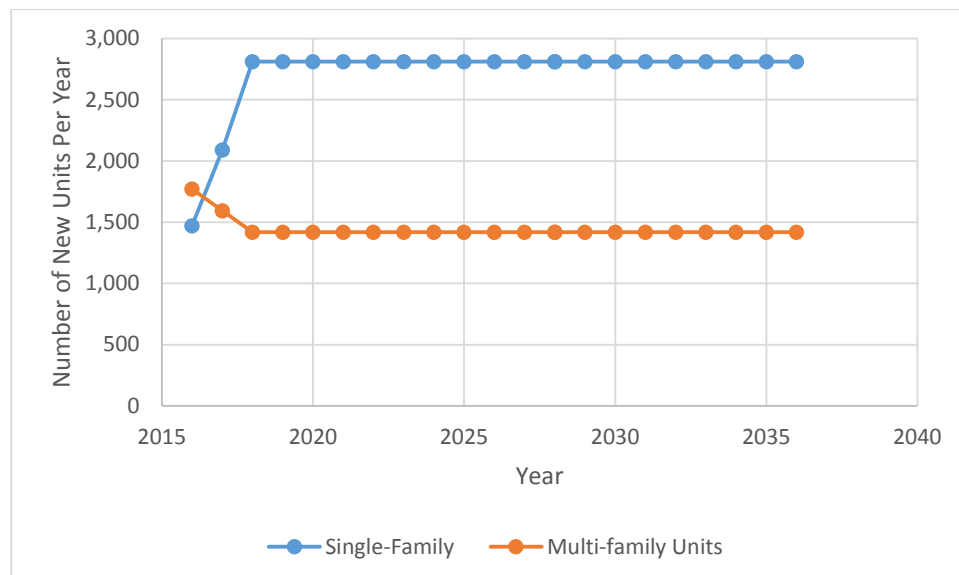
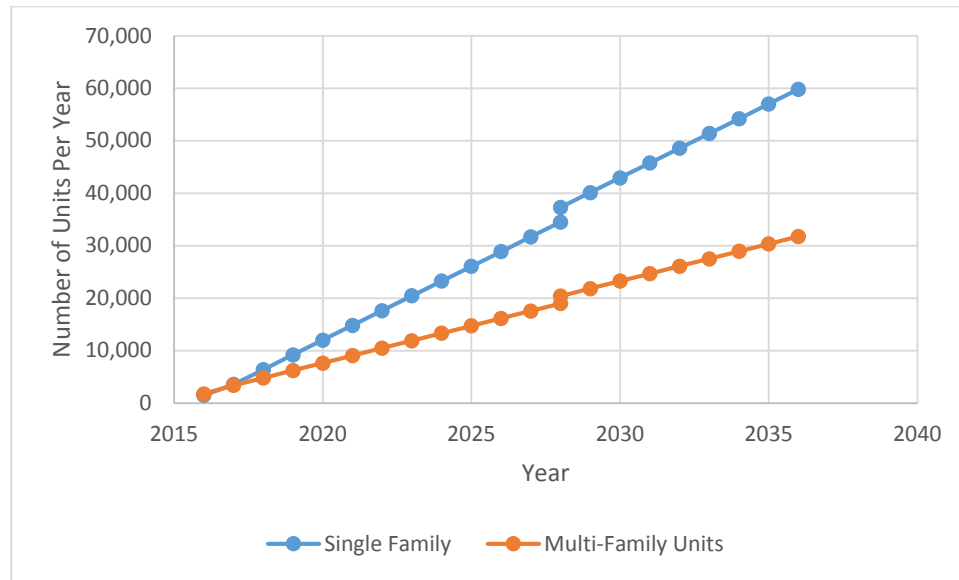
Figure 15. Residential Construction Forecast, Units per Year

Figure 16. Residential Construction Forecast, Cumulative Number of Units

8.3 NONRESIDENTIAL CONSTRUCTION FORECAST

Nonresidential construction for 2016 is estimated to include 430,000 square feet per year of hotels and 1.49 million square feet per year of other nonresidential buildings (Kolderup). This rough estimate is based on Dodge data for permit value and the assumption that the average permit value is \$200 per square foot of floor area. Multi-family buildings 4-stories and greater are included in the nonresidential building category. The cumulative construction forecasts for 2016, 2026, 2030 and 2036 are summarized in Table 16.

Table 16. Nonresidential Construction Forecast, Square Feet of Floor Area¹

Occupancy	Year			
	2016	2026	2030	2036
Hotels	430,000	4,300,000	6,020,000	8,600,000
Other Nonresidential	1,490,000	14,900,000	20,860,000	29,800,000
Total	1,920,000	19,200,000	26,880,000	38,400,000

¹ Dodge data provided by Mary Blewitt, Department of Business, Economic Development, and Tourism

8.4 RESIDENTIAL ENERGY IMPACT FORECAST

The estimated impact of the 2015 IECC with Hawaii amendments on residential energy is an energy savings of 2,048 MWh/yr in 2016 (year 1 representing the first year that the energy code would be adopted) compared to the 2006 IECC. The cumulative total increases to 368,723 MWh/yr in 2026 (year 10); 686,836 MWh/yr in 2030; and 1,316,924 MWh/yr in 2036 (year 20). The cumulative savings estimate assumes that the energy saved by a building constructed in 2016 will save an equal quantity of energy for each year of the study (20 years). The cumulative energy savings for a 20-year analysis (ending in 2036) is the annual energy savings for houses built in 2016 multiplied by the number of years that the homes are in the analysis (20). The savings for a 2016 house is then added to the cumulative savings for houses constructed in 2017 which are only in

the analysis for 19 years, and then to houses built in 2018 (18 years), etc. The process continues until all of the savings for houses built within the 20 period have been totaled. Calculations are summarized in Table 17. These estimates are based on the residential construction forecast described on pages 67 and 68 and the residential energy savings estimates detailed in Section 7 of this report.⁴⁵ The forecast for energy impact was determined as follows:

The cumulative energy savings estimates were determined using EnergyPlus simulations for single-family dwelling units that were assumed to be fully air-conditioned and that complied with the requirements of the 2015 IECC with Hawaii amendments. Energy savings estimates for semi-conditioned buildings were determined assuming that the dwelling unit complied with the Tropical Zone requirements in the 2015 IECC with Hawaii amendments.

- The typical single-family home size is assumed to be 1,700 ft² rather than the 2,400 ft² house used in the analysis (Kolderup). The impact is assumed to reduce proportionately from 2,247 kWh/yr to 1,738 kWh/yr.
- As a rough estimate, 50% of all new homes statewide have air-conditioning and 50% of all new homes either have no air-conditioning or are semi-conditioned. This estimate is based on a Hawaiian Electric Companies (HECO) survey from 2014.
- The energy savings for apartment units is assumed to be 50% of the value calculated for single-family homes equal to 869 kWh/yr per apartment unit (Kolderup).

Table 17. Residential Energy Savings Forecast

Occupancy		Year			
		2016	2026	2030	2036
Single-Family	# Units	1,471	28,878	40,130	57,008
	kWh/yr-unit	1,738	1,738	1,738	1,738
	MWh/yr	1,279	283,178	532,830	1,053,977
Apartment ¹	# Units	1,771	16,146	21,826	30,346
	kWh/yr-unit	869	869	869	869
	MWh/yr	769	85,545	154,006	262,947
Total	# Units	3,242	45,024	61,956	87,354
	MWh/yr	2,048	368,723	686,836	1,316,924

¹ Apartments are 3-stories and less

8.5 NONRESIDENTIAL ENERGY IMPACT FORECAST

The cumulative energy savings estimates were determined for 5 nonresidential occupancy types common to Hawaii construction using EnergyPlus simulations.

The estimated savings for nonresidential buildings under the 2015 IECC with Hawaii amendments is 10,914 MWh/yr compared to ASHRAE Standard 90.1-2004. The cumulative energy savings

⁴⁵ Britt/Makela Group, Inc. "Analyses and Proposal of Hawaii Amendments to the 2015 International Energy Conservation Code." (2014).

increases to 714,867 MWh/yr in 2016 (10 years); 1,304,223 MWh/yr in 2030; and 3,385,815 MWh/yr in 2036 (20 years). Cumulative savings were determined using the same methodology as was used for residential. The savings estimates are summarized in Table 18. This estimate combines construction forecast data described on pages 69 and 70 with the energy savings estimate detailed in Section 7 of this report.

Table 18. Nonresidential Energy Savings Forecast

Occupancy		Year			
		2016	2026	2030	2036
Hotel	ft ²	430,000	4,300,000	6,020,000	8,600,000
	kWh/ft ²	9	9	9	9
	MWh/yr	3,775	247,263	451,113	870,138
Other ¹	ft ²	1,490,000	14,900,000	20,860,000	29,800,000
	kWh/ft ²	5	5	5	5
	MWh/yr	7,139	467,605	853,111	2,515,677
Total	ft ²	1,920,000	19,200,000	26,880,000	38,400,000
	MWh/yr	10,914	714,867	1,304,223	3,385,815

¹ Other includes apartment buildings 4-stories and greater.

8.6 NET ENERGY IMPACT FORECAST

The net overall impact of the 2015 IECC with Hawaii amendments is estimated to be a savings of 12,962 MWh in 2016; 1,083,590 MWh in 2026 (year 10); 1,991,059 MWh in 2030; and 4,702,738 MWh in 2036 (year 20). These estimates are summarized in Table 19 which illustrates the expected energy savings in residential and commercial energy buildings assuming the 2015 IECC with Hawaii amendments is adopted in 2016.

Table 19. Combined Residential and Nonresidential Energy Forecast

Occupancy		Year			
		2016	2026	2030	2036
Residential		2,048	368,723	686,836	1,316,924
Nonresidential		10,914	714,867	1,304,223	3,385,815
Total		12,962	1,083,590	1,991,059	4,702,738

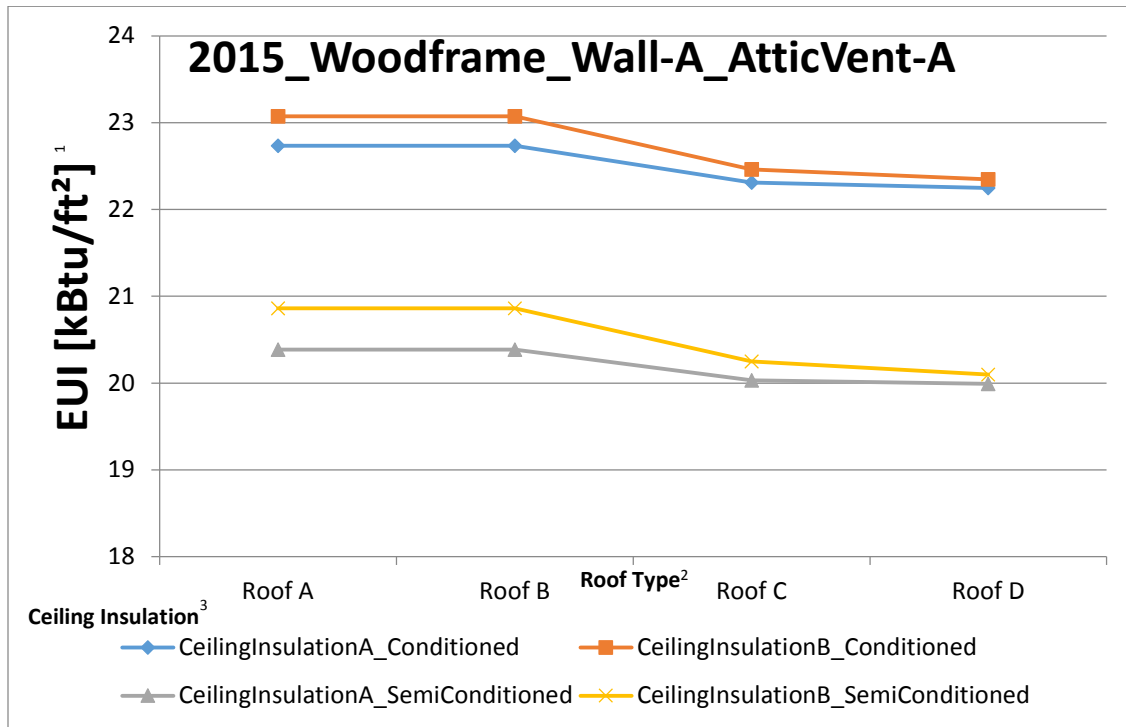
APPENDIX A PARAMETRIC GRAPHS

The graphs contained in Appendix A demonstrate the differences of the Energy Use Index (EUI) for the given assemblies. The different combinations of roof and wall efficiency measures are described in the Legend below. An EUI was calculated for conditioned and semi-conditioned residential buildings and also compared against wood and steel framed wall systems.

Table A 1. Sample Residential Parametric Legend

Parametric Categories		Parametric Description	Designation in Graphs
P1 = wall insulations			
	0	as per code: R13+5 (HEC) and R13+3 (IECC)	Wall-A
	1	no exterior insulation, high reflectance wall	Wall-B
	2	no exterior insulation, high efficacy light	Wall-C
	3	no exterior insulation, exterior shading wpf=0.3	Wall-D
	4	no exterior insulation, SEER 14	Wall-E
P2 = ceiling insulation			
	0	as per code (R-30)	CeilingInsulation-A
	1	reduced to R-19	CeilingInsulation-B
P3 = roof condition			
	0	no roof treatment	Roof-A
	1	radiant barrier	Roof-B
	2	cool roof	Roof-C
	3	cool roof + radiant barrier	Roof-D
P4 = attic vent			
	0	no attic vent	AtticVent-A
	1	attic vent = 0.5 cfm/sf	AtticVent-B
	2	attic vent = 1.0 cfm/sf	AtticVent-C
	3	attic vent = 1.5 cfm/sf	AtticVent-D

Table A 2. Wood Framed Wall with *Minimum Attic Ventilation* Compared to Roof Types and Ceiling Insulation R-values



¹ EUI = Energy Use Index (kBtu/ft²)

² Roof Type A: No roof treatment

Roof Type B: Radiant barrier

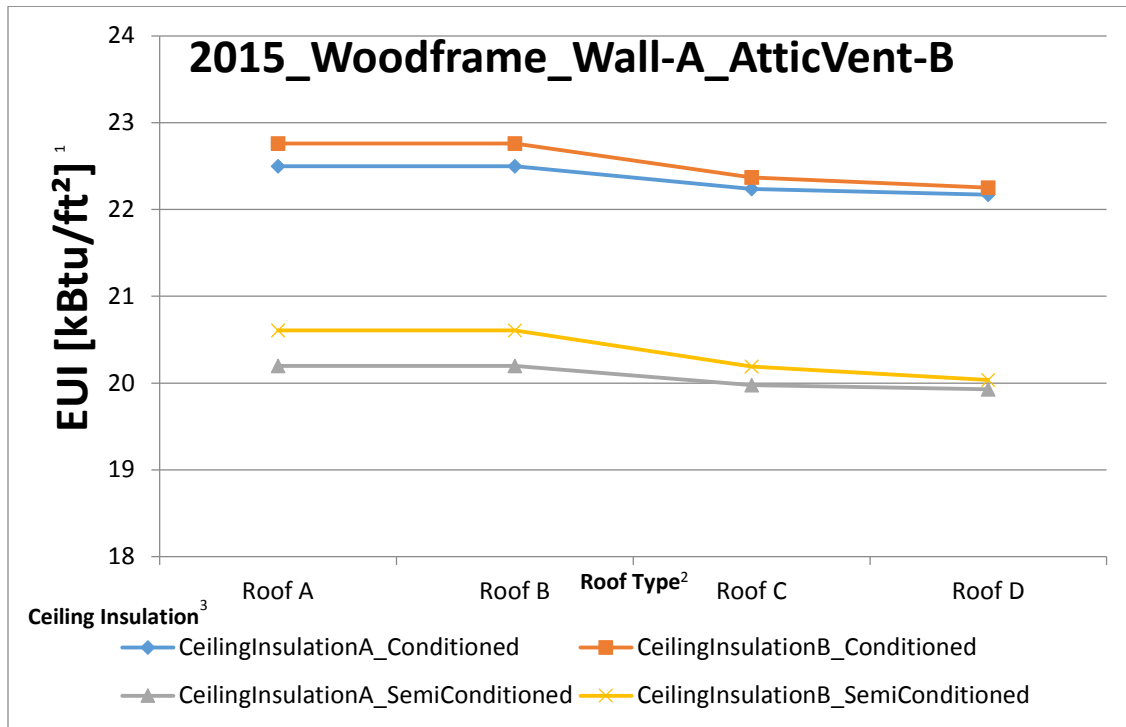
Roof Type C: Cool roof

Roof Type D: Cool roof + radiant barrier

³ Ceiling Insulation A: R-30

Ceiling Insulation B: R-19

Table A 3. Wood Framed Wall with 0.5 cfm/sf Attic Ventilation Compared to Roof Types and Ceiling Insulation R-values



¹ EUI = Energy Use Index (kBtu/ft²)

² Roof Type A: No roof treatment

Roof Type B: Radiant barrier

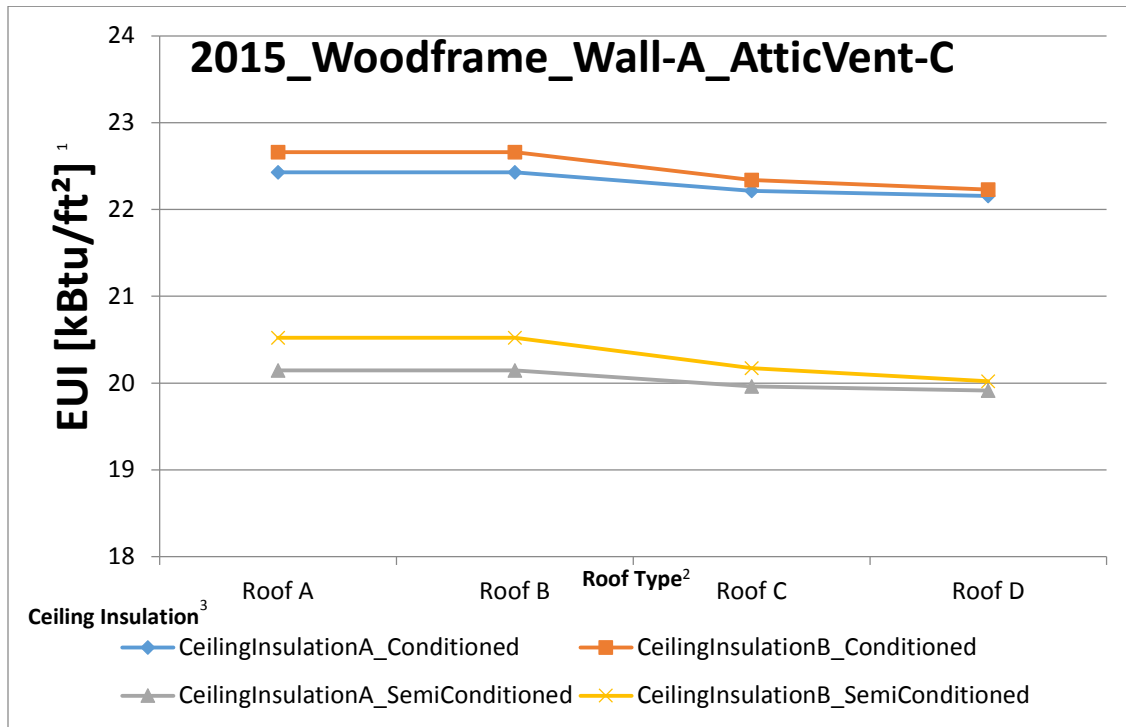
Roof Type C: Cool roof

Roof Type D: Cool roof + radiant barrier

³ Ceiling Insulation A: R-30

Ceiling Insulation B: R-19

Table A 4. Wood Framed Wall with 1.0 cfm/sf Attic Ventilation Compared to Roof Types and Ceiling Insulation R-values



¹ EUI = Energy Use Index (kBtu/ft²)

² Roof Type A: No roof treatment

Roof Type B: Radiant barrier

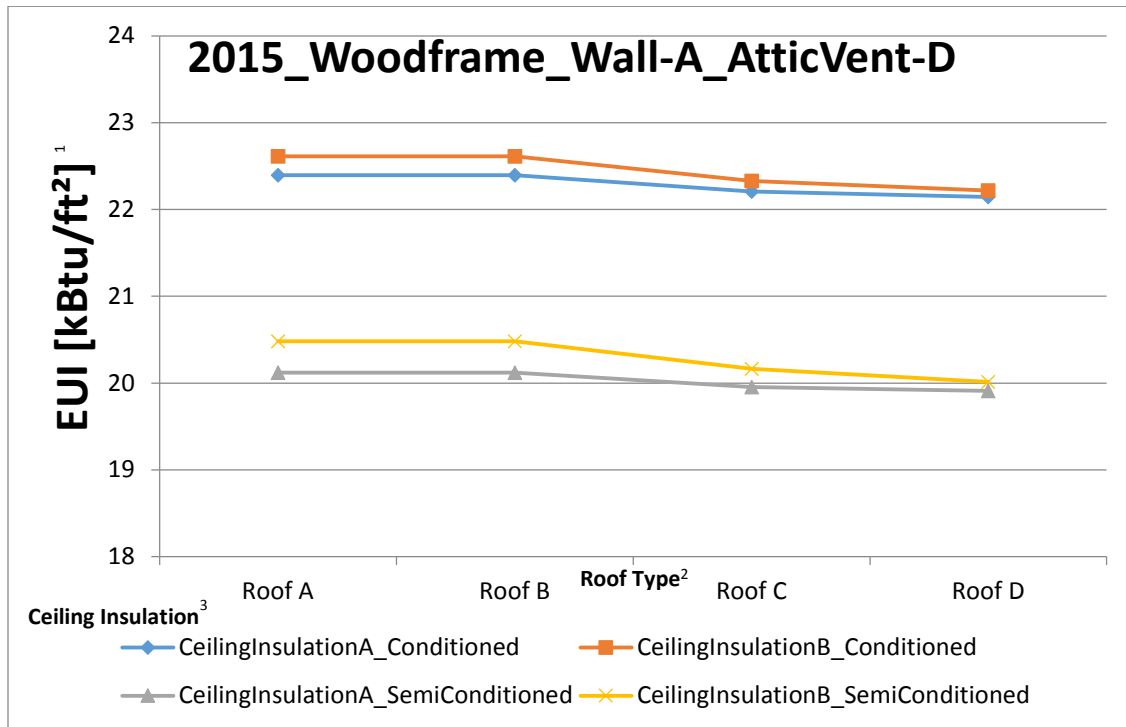
Roof Type C: Cool roof

Roof Type D: Cool roof + radiant barrier

³ Ceiling Insulation A: R-30

Ceiling Insulation B: R-19

Table A 5. Wood Framed Wall with 1.5 cfm/sf Attic Ventilation Compared to Roof Types and Ceiling Insulation R-values



¹ EUI = Energy Use Index (kBtu/ft²)

² Roof Type A: No roof treatment

Roof Type B: Radiant barrier

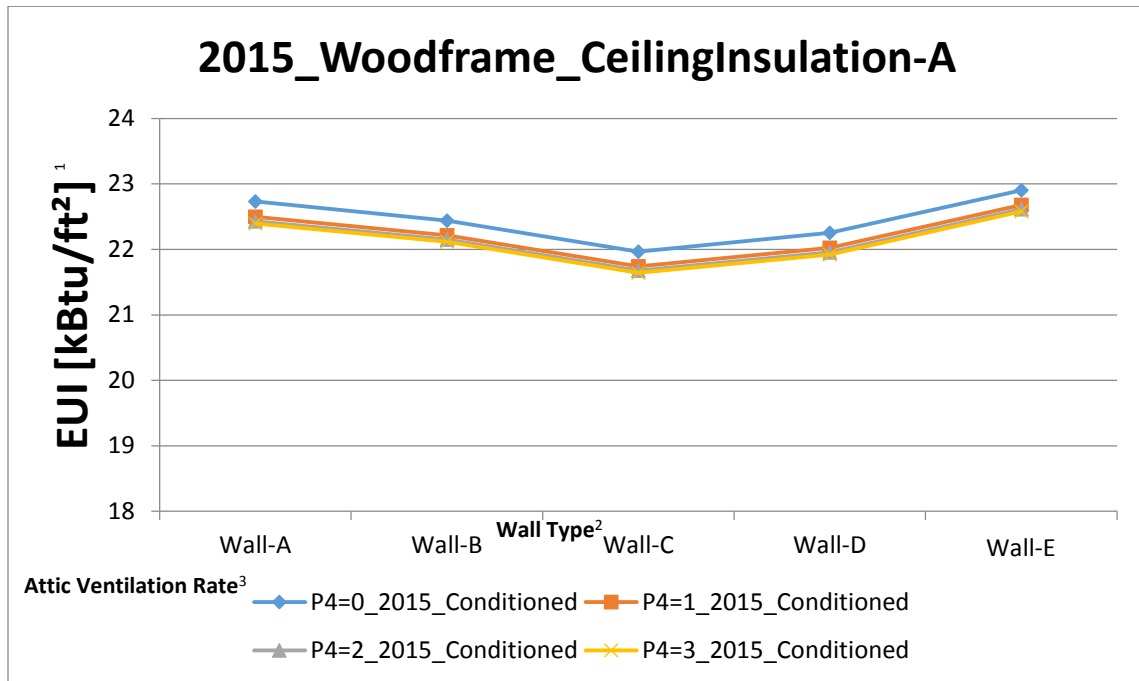
Roof Type C: Cool roof

Roof Type D: Cool roof + radiant barrier

³ Ceiling Insulation A: R-30

Ceiling Insulation B: R-19

Table A 6. Wood Framed Wall with R-30 Ceiling Insulation Compared to Wall Types and Roof Ventilation for Conditioned Buildings



¹ EUI = Energy Use Index (kBtu/ft²)

² Wall Type A: Per code: R13+5 (HEC) and R13+3 (IECC)

Wall Type B: No exterior insulation, high reflectance surface on wall

Wall Type C: No exterior insulation, high efficacy lighting

Wall Type D: No exterior insulation, exterior shading WPF=0.3

Wall Type E: No exterior insulation, SEER 14

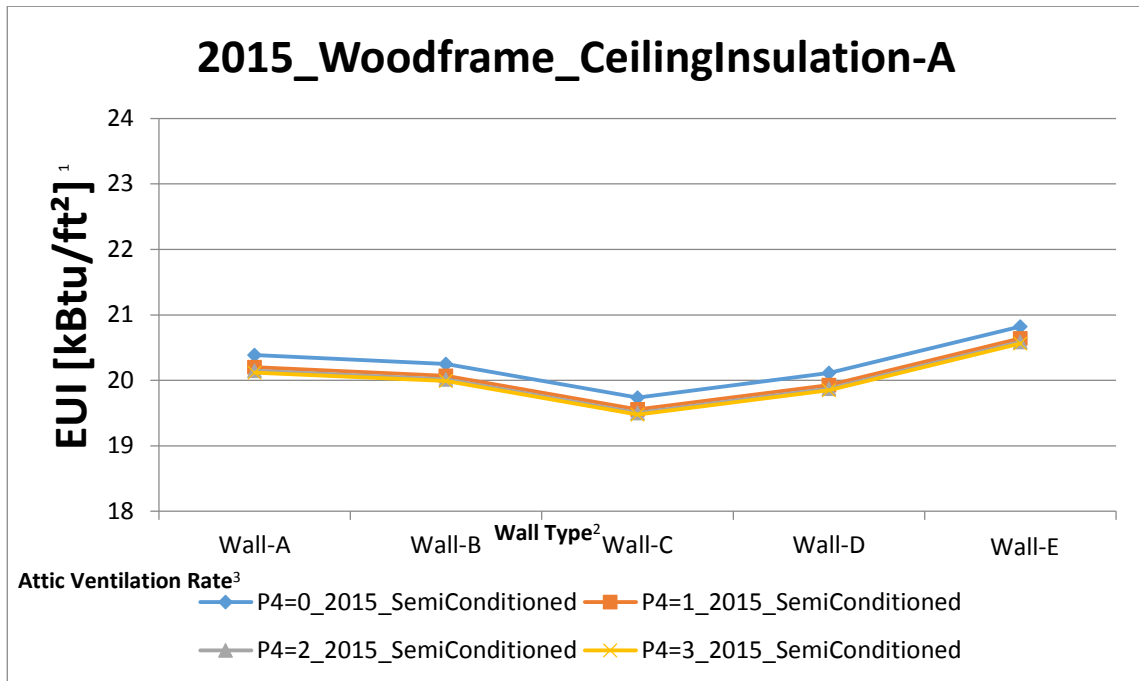
³ Attic Ventilation Rate P4 = 0: Minimum code attic ventilation

Attic Ventilation Rate P4 = 1: 0.5 cfm/sf

Attic Ventilation Rate P4 = 2: 1.0 cfm/sf

Attic Ventilation Rate P4 = 3: 1.5 cfm/sf

Table A 7. Wood Framed Wall with R-30 Ceiling Insulation Compared to Wall Types and Roof Ventilation for Semi-Conditioned Buildings



¹ EUI = Energy Use Index (kBtu/ft²)

² Wall Type A: Per code: R13+5 (HEC) and R13+3 (IECC)

Wall Type B: No exterior insulation, high reflectance surface on wall

Wall Type C: No exterior insulation, high efficacy lighting

Wall Type D: No exterior insulation, exterior shading WPF=0.3

Wall Type E: No exterior insulation, SEER 14

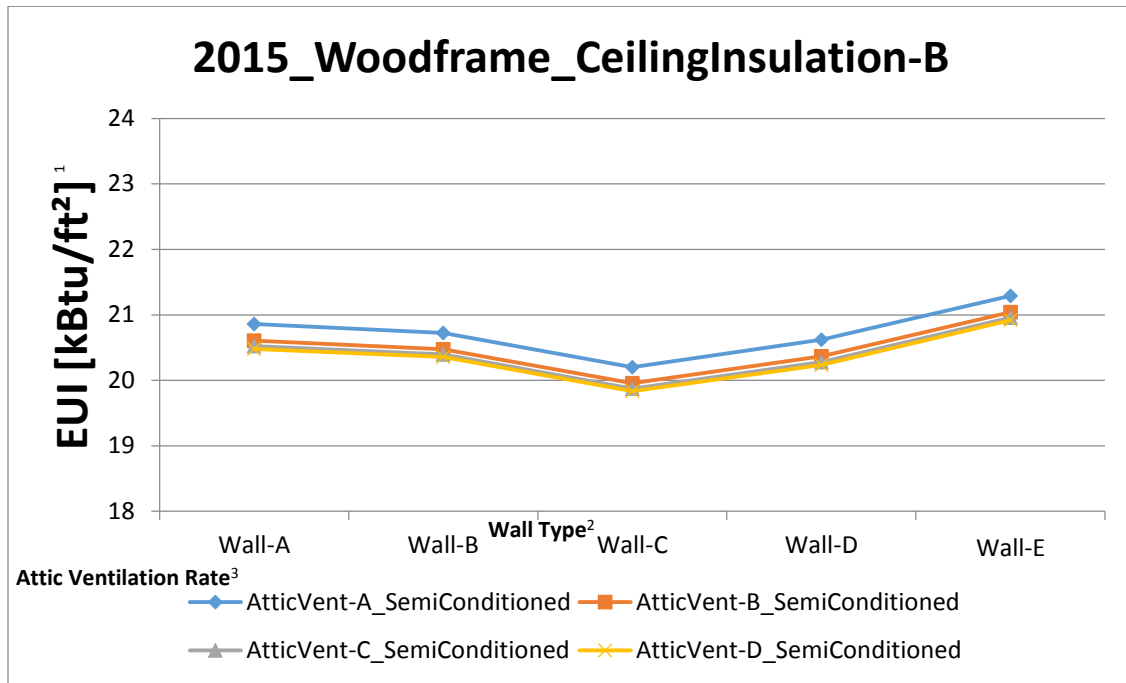
³ Attic Ventilation Rate P4 = 0: Minimum code attic ventilation

Attic Ventilation Rate P4 = 1: 0.5 cfm/sf

Attic Ventilation Rate P4 = 2: 1.0 cfm/sf

Attic Ventilation Rate P4 = 3: 1.5 cfm/sf

Table A 8. Wood Framed Wall with R-19 Ceiling Insulation Compared to Wall Types and Roof Ventilation for Semi-Conditioned Buildings



¹ EUI = Energy Use Index (kBtu/ft²)

² Wall Type A: Per code: R13+5 (HEC) and R13+3 (IECC)

Wall Type B: No exterior insulation, high reflectance surface on wall

Wall Type C: No exterior insulation, high efficacy lighting

Wall Type D: No exterior insulation, exterior shading WPF=0.3

Wall Type E: No exterior insulation, SEER 14

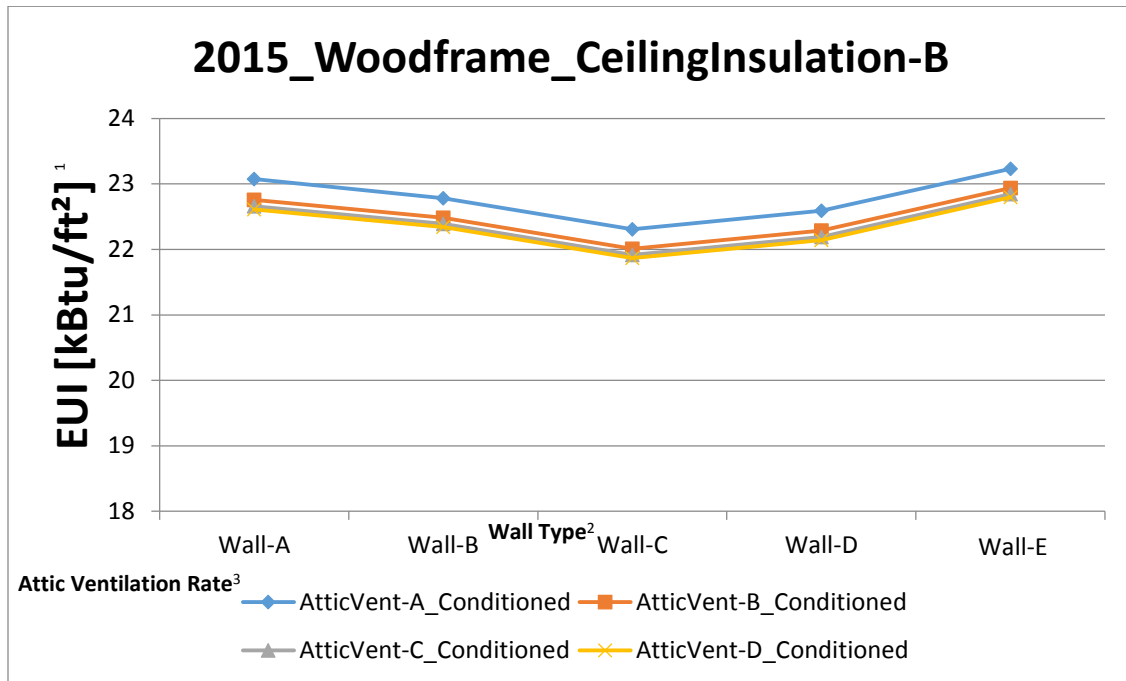
³ Attic Ventilation Rate A: Minimum code attic ventilation

Attic Ventilation Rate B: 0.5 cfm/sf

Attic Ventilation Rate C: 1.0 cfm/sf

Attic Ventilation Rate D: 1.5 cfm/sf

Table A 9. Wood Framed Wall with R-19 Ceiling Insulation Compared to Wall Types and Roof Ventilation for Conditioned Buildings



¹ EUI = Energy Use Index (kBtu/ft²)

² Wall Type A: Per code: R13+5 (HEC) and R13+3 (IECC)

Wall Type B: No exterior insulation, high reflectance surface on wall

Wall Type C: No exterior insulation, high efficacy lighting

Wall Type D: No exterior insulation, exterior shading WPF=0.3

Wall Type E: No exterior insulation, SEER 14

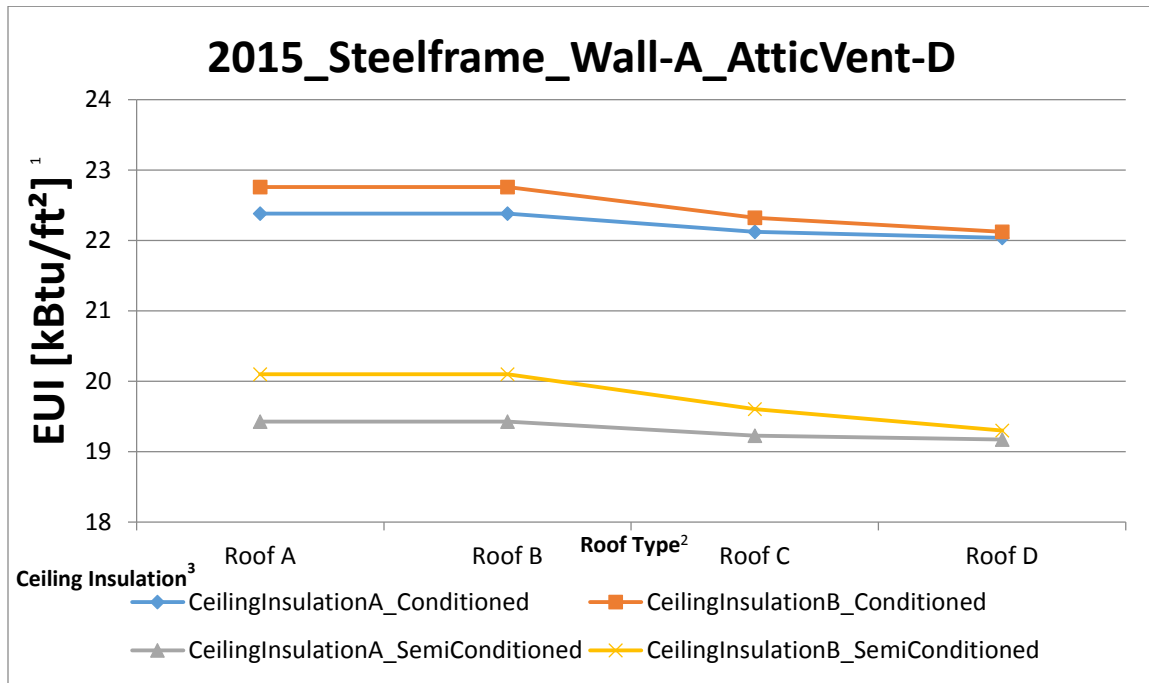
³ Attic Ventilation Rate A: Minimum code attic ventilation

Attic Ventilation Rate B: 0.5 cfm/sf

Attic Ventilation Rate C: 1.0 cfm/sf

Attic Ventilation Rate D: 1.5 cfm/sf

Table A 10. Steel Framed Wall with 1.5 cfm/sf Attic Ventilation Compared to Wall Types and Ceiling Insulation for Conditioned Buildings and Semi-Conditioned



¹ EUI = Energy Use Index (kBtu/ft²)

² Roof Type A: No roof treatment

Roof Type B: Radiant barrier

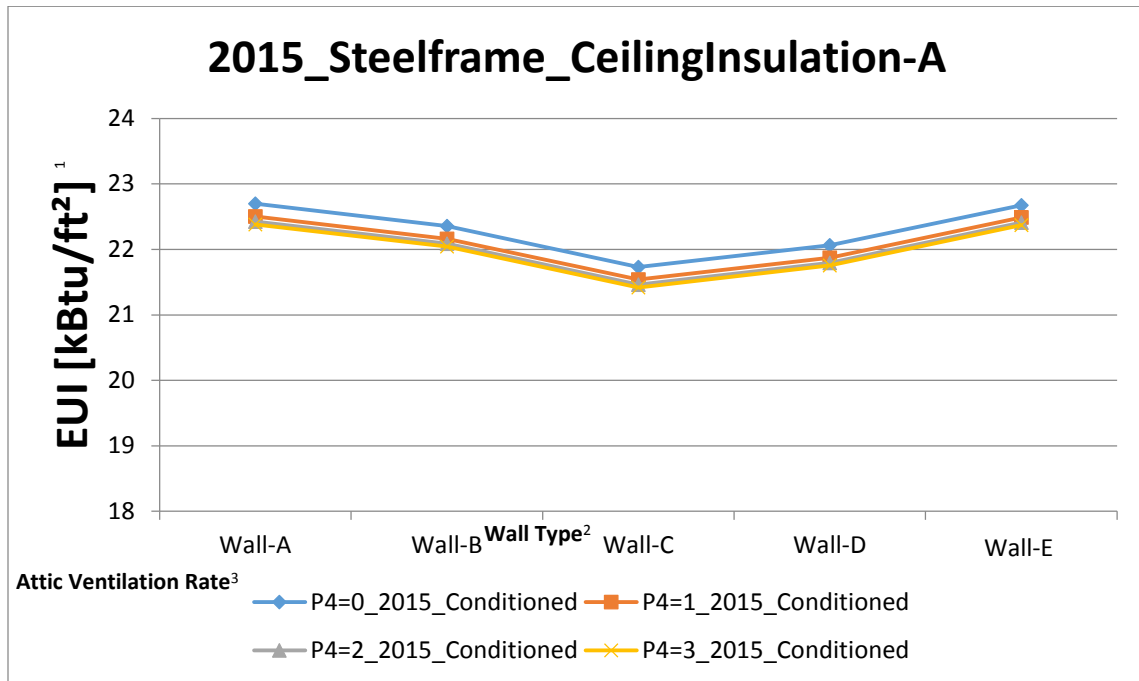
Roof Type C: Cool roof

Roof Type D: Cool roof + radiant barrier

³ Ceiling Insulation A: R-30

Ceiling Insulation B: R-19

Table A 11. Steel Framed Wall with R-30 Ceiling Insulation Compared to Wall Types and Roof Ventilation for Conditioned Buildings



¹ EUI = Energy Use Index (kBtu/ft²)

² Wall Type A: Per code: R13+5 (HEC) and R13+3 (IECC)

Wall Type B: No exterior insulation, high reflectance surface on wall

Wall Type C: No exterior insulation, high efficacy lighting

Wall Type D: No exterior insulation, exterior shading WPF=0.3

Wall Type E: No exterior insulation, SEER 14

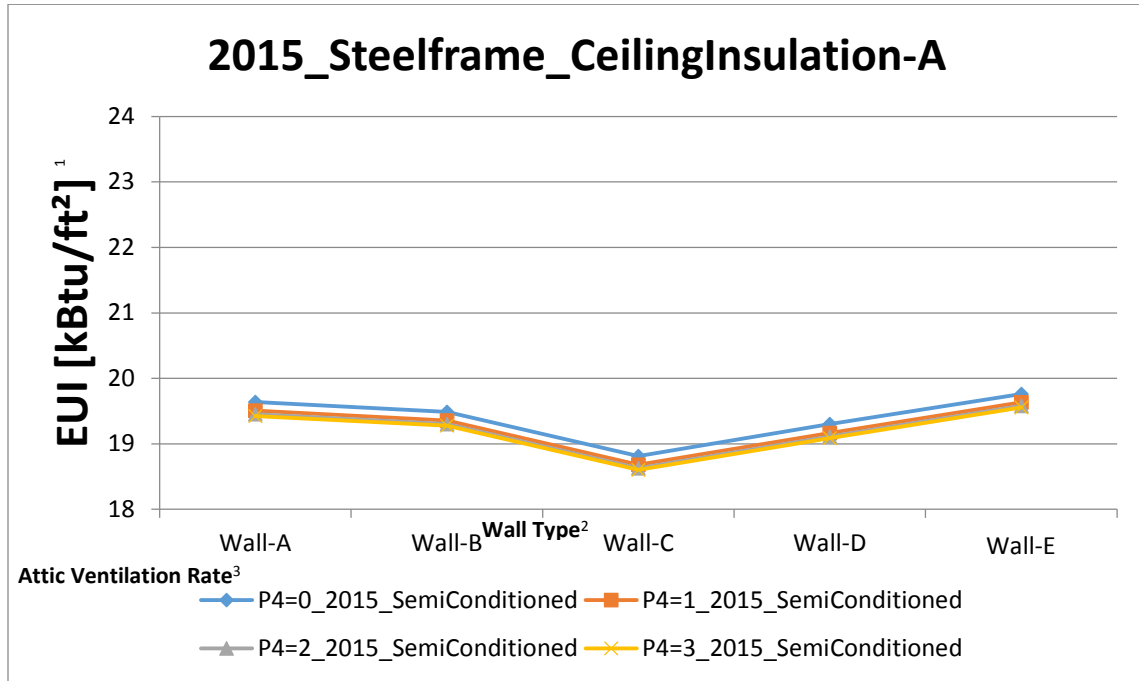
³ Attic Ventilation Rate P4 = 0: Minimum code attic ventilation

Attic Ventilation Rate P4 = 1: 0.5 cfm/sf

Attic Ventilation Rate P4 = 2: 1.0 cfm/sf

Attic Ventilation Rate P4 = 3: 1.5 cfm/sf

Table A 12. Steel Framed Wall with R-30 Ceiling Insulation Compared to Wall Types and Roof Ventilation for Semi-Conditioned Buildings



¹ EUI = Energy Use Index (kBtu/ft²)

² Wall Type A: Per code: R13+5 (HEC) and R13+3 (IECC)

Wall Type B: No exterior insulation, high reflectance surface on wall

Wall Type C: No exterior insulation, high efficacy lighting

Wall Type D: No exterior insulation, exterior shading WPF=0.3

Wall Type E: No exterior insulation, SEER 14

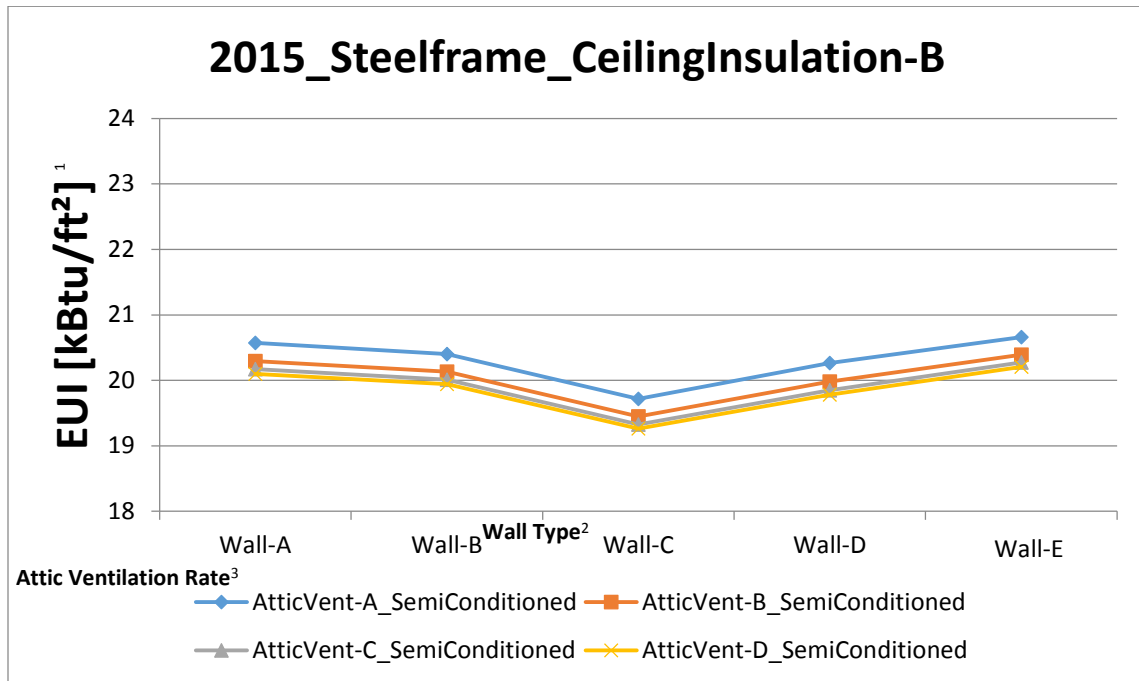
³ Attic Ventilation Rate P4 = 0: Minimum code attic ventilation

Attic Ventilation Rate P4 = 1: 0.5 cfm/sf

Attic Ventilation Rate P4 = 2: 1.0 cfm/sf

Attic Ventilation Rate P4 = 3: 1.5 cfm/sf

Table A 13. Steel Framed Wall with R-19 Ceiling Insulation Compared to Wall Types and Roof Ventilation for Semi-Conditioned Buildings



¹ EUI = Energy Use Index (kBtu/ft²)

² Wall Type A: Per code: R13+5 (HEC) and R13+3 (IECC)

Wall Type B: No exterior insulation, high reflectance surface on wall

Wall Type C: No exterior insulation, high efficacy lighting

Wall Type D: No exterior insulation, exterior shading WPF=0.3

Wall Type E: No exterior insulation, SEER 14

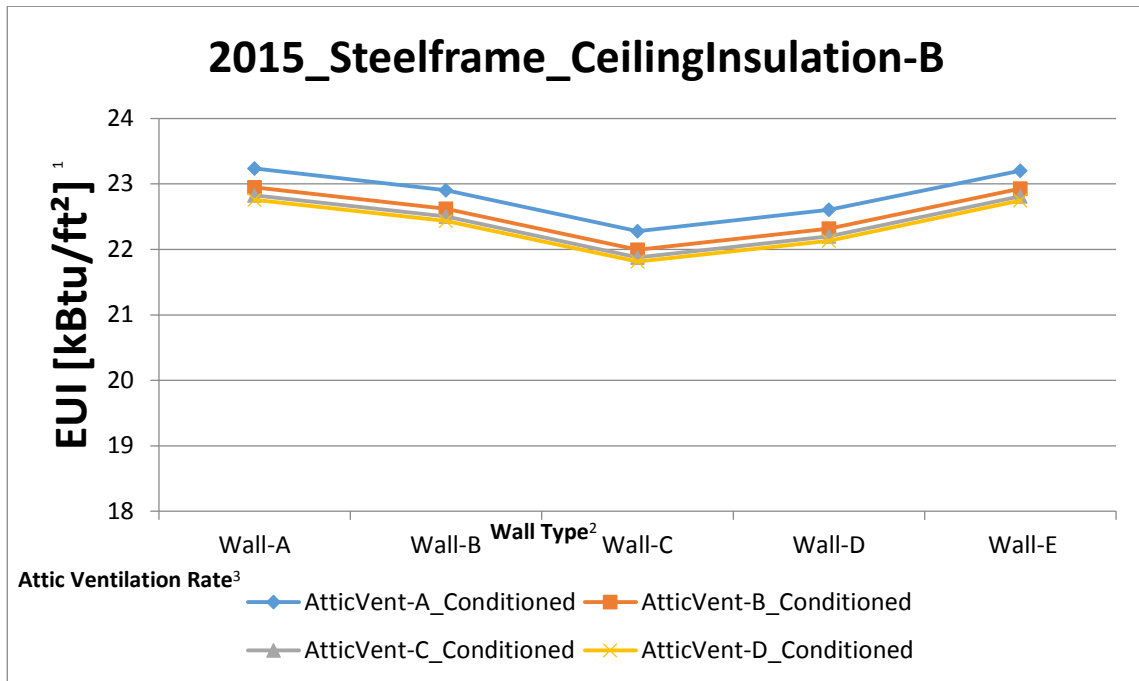
³ Attic Ventilation Rate P4 = 0: Minimum code attic ventilation

Attic Ventilation Rate P4 = 1: 0.5 cfm/sf

Attic Ventilation Rate P4 = 2: 1.0 cfm/sf

Attic Ventilation Rate P4 = 3: 1.5 cfm/sf

Table A 14. Steel Framed Wall with R-19 Ceiling Insulation Compared to Wall Types and Roof Ventilation for Conditioned Buildings



¹ EUI = Energy Use Index (kBtu/ft²)

² Wall Type A: Per code: R13+5 (HEC) and R13+3 (IECC)

Wall Type B: No exterior insulation, high reflectance surface on wall

Wall Type C: No exterior insulation, high efficacy lighting

Wall Type D: No exterior insulation, exterior shading WPF=0.3

Wall Type E: No exterior insulation, SEER 14

³ Attic Ventilation Rate A: Minimum code attic ventilation

Attic Ventilation Rate B: 0.5 cfm/sf

Attic Ventilation Rate C: 1.0 cfm/sf

Attic Ventilation Rate D: 1.5 cfm/sf