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Sponsor: State of Hawaii, Department of Business, Economic Development and Tourism

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Learning Objectives

• Determine energy code compliance for building envelope designs
• Identify effective envelope heat gain reduction strategies
• Develop fenestration designs that account for thermal and visual comfort
• Select effective opaque envelope construction options
• Identify applicable County amendments to the International Energy Conservation Code
# Agenda – Morning Session

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00</td>
<td>Registration</td>
</tr>
<tr>
<td>8:30</td>
<td>Introduction</td>
</tr>
<tr>
<td></td>
<td>Fenestration design</td>
</tr>
<tr>
<td></td>
<td>Fenestration requirements</td>
</tr>
<tr>
<td>9:45</td>
<td>BREAK</td>
</tr>
<tr>
<td>10:00</td>
<td>Opaque envelope design</td>
</tr>
<tr>
<td></td>
<td>Opaque envelope requirements</td>
</tr>
<tr>
<td></td>
<td>Hawaii Energy</td>
</tr>
<tr>
<td>11:30</td>
<td>Adjourn</td>
</tr>
</tbody>
</table>
# Agenda – Afternoon Session

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>1:00</td>
<td>Registration</td>
</tr>
<tr>
<td>1:30</td>
<td>Hawaii Energy</td>
</tr>
<tr>
<td>1:40</td>
<td>Introduction</td>
</tr>
<tr>
<td></td>
<td>Fenestration design</td>
</tr>
<tr>
<td></td>
<td>Fenestration requirements</td>
</tr>
<tr>
<td>3:00</td>
<td>BREAK</td>
</tr>
<tr>
<td>3:15</td>
<td>Opaque envelope design</td>
</tr>
<tr>
<td></td>
<td>Opaque envelope requirements</td>
</tr>
<tr>
<td>4:30</td>
<td>Adjourn</td>
</tr>
</tbody>
</table>
Section 1

Introduction
What is it?

DEPARTMENT OF ACCOUNTING AND GENERAL SERVICES

Repeal of Chapter 3-181
and
Adoption of Chapter 3-181.1

Hawaii Administrative Rules

State amendments
March 2017


County Adoption Status

Kauai – Nov. 2018
Maui – Mar. 2019
Honolulu
Hawaii  \[\text{State amendments apply as of March 2019}\]
Table of Contents

Commercial Provisions
Chapter 1 – Scope and Administration *
Chapter 2 – Definitions
Chapter 3 – General Requirements
Chapter 4 – Commercial Energy Efficiency *
Chapter 5 – Existing Buildings *
Chapter 6 – References Standards

Residential Provisions
Chapter 1 – Scope and Administration *
Chapter 2 – Definitions
Chapter 3 – General Requirements
Chapter 4 – Residential Energy Efficiency *
Chapter 5 – Existing Buildings *
Chapter 6 – References Standards

* See also Hawai‘i State Energy Conservation Code amendments
Who needs to comply?

Residential Requirements
• 1- and 2-family dwellings (R-3)
• Multi-family (R-2 ≤ 3 stories)
• Residential care/assisted living (R-4 ≤ 3 stories)

Commercial Requirements
• All other buildings
  - Including R-1 (hotels)
Who needs to comply?

• New construction
• Additions
• Alterations
  - Several exceptions
• Change of occupancy
  - When change results in increase in energy
  - Conversions to dwellings
Why should I care?

• Energy savings
  - Lower utility bills
  - Reduced oil imports
  - Lower emissions

• Value
  - Lower life-cycle cost

• Comfort
Why should I care?

Electricity Rates ($/kWh)

Expensive energy

Why should I care?

Hawaii Electricity Production by Source (2016)

- Petroleum: 61.6%
- Coal: 13.9%
- Other: 3.0%
- Other Gases: 0.5%
- Other Sources: 3.0%
- Biomass: 3.3%
- Geothermal: 2.4%
- Hydro: 0.8%
- Wind: 5.9%
- Solar: 0.8%
- Customer PV: 7.7%

Imported energy

Source: Eugene Tian, DBEDT
Why should I care?

Residential Electricity (kWh/year)

Source: Hawaii Data Book 2017

Some good news
Why are we talking about envelope?

2018 code compliance study

Window compliance

Residential

- Complies 20%
- Does Not Comply 0%
- Unknown 80%

Commercial

- Complies 7%
- Partial compliance 6%
- Does not comply 13%
- Unknown 74%

Why are we talking about envelope?

2018 code compliance study

Roof insulation compliance

Residential:
- Unknown: 27%
- Does Not Comply: 1%
- Complies: 72%

Commercial:
- Unknown: 31%
- Does not comply: 10%
- Complies: 59%

Section 2
Fenestration Design

- Window impacts
- How windows work
- Window design strategies
Window Impacts

Views, aesthetics, and

- Cooling system size
- Energy - air conditioning and lighting
- Peak electric demand
- Occupant thermal comfort
- Indoor visual comfort
- Outdoor reflected light and heat
Heat Gain Sources

**External sources**
- Solar radiation
- Conduction
  - Windows
  - Opaque envelope
- Infiltration

**Internal sources**
- Lighting
- Occupants
- Office equipment
Window Impacts

Example office building

30% window area

60% window area

Peak space cooling load

- Window solar
- Window conductance
- Roof
- Walls
- Infiltration
- Occupants
- Lighting
- Plugs

30%

60%
Window Impacts

Example office building

30% window area

60% window area

Site EUI (kBtu/sf-yr)

- 30% WWR SHGC 0.25: 29.0
- 60% WWR SHGC 0.25: 31.1

+7%

Total
- Cooling
- Vent. Fans
- Plugs
- Area Lights
Window Impacts

Example office building

30% window area

60% window area

Peak Electric Demand (kW)

+13%

30% WWR SHGC 0.25

93

60% WWR SHGC 0.25

105
Window Impacts

Example office building

30% window area

60% window area

Cooling System Capacity (tons)

Source: www.carrier.com
Window Impacts

Example office building

30% window area

60% window area

Cooling System Airflow (cfm)

+30%

30% WWR SHGC 0.25: 17,172
60% WWR SHGC 0.25: 22,302
Window Impacts

Thermal comfort

Mean radiant temperature (MRT)

Direct sun (shortwave radiation)

Surface temperature (longwave radiation)
Window Impacts

Single-pane tinted glass
- 90F outdoor air
- Sun on window

- MRT = 88F
  - Need 74F air
  - + direct sun: MRT = 91F
  - Need 67F air

Dual pane low-e, low solar gain

- MRT = 77F
  - Need 78F air
  - + direct sun: MRT = 82F
  - Need 74F air
Visual comfort

Typical indoor lighting targets

<table>
<thead>
<tr>
<th>Activity</th>
<th>Illuminance (footcandles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circulation Orientation</td>
<td>2</td>
</tr>
<tr>
<td>Public Areas</td>
<td>5</td>
</tr>
<tr>
<td>Simple Tasks</td>
<td>10</td>
</tr>
<tr>
<td>Large Tasks Good Contrast</td>
<td>30</td>
</tr>
<tr>
<td>Small Tasks Good Contrast</td>
<td>50</td>
</tr>
<tr>
<td>Small Tasks Poor Contrast</td>
<td>100</td>
</tr>
</tbody>
</table>

Daylight illuminance

<table>
<thead>
<tr>
<th>Daylight condition</th>
<th>Illuminance (footcandles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear sky</td>
<td>2,000 to 10,000</td>
</tr>
<tr>
<td>Overcast sky</td>
<td>500 to 2,000</td>
</tr>
</tbody>
</table>
Window Impacts

Visual comfort

Glare
- Disability glare
- Discomfort glare
  - Direct glare
  - Veiling glare (reflections)

Maximum Luminance (Brightness) Ratios

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 : 3</td>
<td>task and adjacent surrounding</td>
</tr>
<tr>
<td>1 : 10</td>
<td>task and more remote surfaces</td>
</tr>
<tr>
<td>1 : 40</td>
<td>within the normal field of view</td>
</tr>
</tbody>
</table>
Reflected light and heat

Reflective "death ray" torments Vegas sunbathers

LAS VEGAS (Reuters) - MGM Resorts International is taking the heat for an intense beam of searing desert sunlight, jokingly dubbed the "death ray," that some hotel guests say poses a risk of severe burns to bathers lounging poolside.

'Walkie Scorchie' building developers say they will erect temporary scaffold

Local business owners blame the London skyscraper for starting fires and causing damage by reflecting the sun's rays.

▲ The 37-storey tower has been blamed for blistering paintwork, smashed tiles and singed fabric. Photograph: Andy Scott/PAT Press Association

Tue 3 Sep 2013 15:21 EDT
How windows work

Incoming solar radiation

Conduction

Inward heat flow by convection and longwave radiation

Reflected solar radiation

Absorbed solar radiation

Transmitted solar shortwave radiation

Outward heat flow by convection and longwave radiation

Reflected + Absorbed + Transmitted = 1
How windows work

Dual-pane glazing

Radiation and convection within gap

Additional reflections
How windows work

No coating

With low-emittance (low-e) coating

\[ q_{net\ 1\ to\ 2} = \frac{\sigma (T_1^4 - T_2^4)}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1} \]

\( \epsilon = \) infrared emittance

Could also be on this surface
How windows work

- **Thermal characteristics**
  - Solar heat gain coefficient (SHGC)
  - Thermal conductance (U-factor)

- **Optical characteristics**
  - Visible light transmittance (VLT)
How windows work

Solar heat gain coefficient

\[ \text{SHGC} = \frac{\text{Solar heat gain entering the space}}{\text{Incident solar radiation energy}} \]
How windows work

Solar heat gain coefficient

Clear glass

\[ \text{SHGC} = 80\% + 6\% = 86\% \]

How windows work

Solar heat gain coefficient

Tinted glass (heat-absorbing)

SHGC = 40% + 12% = 52%

(An example. A range of performance is available)

Solar heat gain coefficient

Reflective glass coating

\[ \text{SHGC} = 50\% + 6\% = 56\% \]

(An example. A range of performance is available)

Visible light transmittance

$$\text{VLT} = \frac{\text{Visible light entering the space}}{\text{Incident visible light}}$$

Examples

- Clear glass: VLT = 0.88
- Tinted glass: VLT = ~0.50
Solar Spectrum

- Outside Atmosphere
- Earth Surface

Ultra-violet: 380-720 nm
Visible: 380-720 nm
Infrared (shortwave)

Solar Radiation (W/m²-nm)

Wavelength (nm)

Data source: http://rredc.nrel.gov/solar/spectra/
Solar Radiation Power

At Earth Surface

<table>
<thead>
<tr>
<th>Type</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraviolet</td>
<td>10 Btu/hr-ft$^2$</td>
</tr>
<tr>
<td>Visible</td>
<td>149 Btu/hr-ft$^2$</td>
</tr>
<tr>
<td>Infrared</td>
<td>158 Btu/hr-ft$^2$</td>
</tr>
<tr>
<td>Total</td>
<td>317 Btu/hr-ft$^2$</td>
</tr>
</tbody>
</table>
How windows work

Tinted glass examples

[Graph showing solar radiation and transmittance across different wavelengths for clear, gray tint, and green tint glasses.]

- Ultra-violet (380-720 nm)
- Visible
- Infrared (shortwave)

- Clear glass
- Gray tint glass
- Green tint glass
How windows work

Tinted glass examples

<table>
<thead>
<tr>
<th>Glass Type (all ¼ in.)</th>
<th>SHGC</th>
<th>VLT</th>
<th>VLT/SHGC ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>clear</td>
<td>0.82</td>
<td>0.88</td>
<td>1.1</td>
</tr>
<tr>
<td>gray</td>
<td>0.60</td>
<td>0.47</td>
<td>0.78</td>
</tr>
<tr>
<td>green</td>
<td>0.61</td>
<td>0.77</td>
<td>1.26</td>
</tr>
</tbody>
</table>

Spectrally selective
How windows work

Coated glass

Range of performance
- U-factor (emittance)
- SHGC
- VLT
How windows work

Coated glass examples

- SHGC 0.82, VLT 0.88
- SHGC 0.63, VLT 0.73
- SHGC 0.38, VLT 0.71
- SHGC 0.18, VLT 0.31
How windows work

Three-layer silver coating

- Top coat
  - anti-reflective dielectric
  - silver 10-15 nm
  - anti-reflective dielectric
  - silver 10-15 nm
  - anti-reflective dielectric
  - silver 10-15 nm
- Base
  - ~6,000,000 nm glass thickness

<250 nm
Identifying coated glass

Surface 1  Surface 2  Surface 3  Surface 4

Outside  Coating  Inside

Outside  Coating  Inside

Outside  Coating  Inside

Outside  Coating  Inside

Outside  Coating  Inside
Surface reflections

Coating on #2 surface
### Table 10  Visible Transmittance $T_v$, Solar Heat Gain Coefficient (SHGC), Solar Transmittance $T$, Front Reflectance $R_f$, Back Reflectance $R_b$, and Layer Absorptance $A_{nf}$ for Glazing and Window Systems

<table>
<thead>
<tr>
<th>Glass System</th>
<th>Center-of-Glazing Properties</th>
<th>Incidence Angles</th>
<th>Aluminum Operable</th>
<th>Other Frames Operable</th>
<th>Aluminum Operable</th>
<th>Other Frames Operable</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Uncoated Single Glazing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1b 1/4 CLR</td>
<td>0.88 SHGC</td>
<td>0.81 0.80 0.78 0.73 0.62 0.39 0.73</td>
<td>0.74</td>
<td>0.74</td>
<td>0.66 0.72</td>
<td>0.78 0.79 0.70 0.77</td>
</tr>
<tr>
<td>1h 1/4 GRY</td>
<td>0.46 SHGC</td>
<td>0.59 0.57 0.55 0.51 0.44 0.28 0.52</td>
<td>0.54</td>
<td>0.54</td>
<td>0.48 0.52</td>
<td>0.41 0.41 0.37 0.40</td>
</tr>
<tr>
<td>1i 1/4 BLUGRN</td>
<td>0.75 SHGC</td>
<td>0.62 0.59 0.57 0.54 0.46 0.30 0.55</td>
<td>0.57</td>
<td>0.57</td>
<td>0.50 0.55</td>
<td>0.67 0.68 0.60 0.66</td>
</tr>
<tr>
<td><strong>Reflective Single Glazing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1j 1/4 SS on CLR 8%</td>
<td>0.08 SHGC</td>
<td>0.19 0.19 0.19 0.18 0.16 0.10 0.18</td>
<td>0.18</td>
<td>0.18</td>
<td>0.16 0.17</td>
<td>0.07 0.07 0.06 0.07</td>
</tr>
<tr>
<td>1n 1/4 Ti on CLR 20%</td>
<td>0.20 SHGC</td>
<td>0.29 0.29 0.28 0.27 0.23 0.15 0.27</td>
<td>0.27</td>
<td>0.27</td>
<td>0.24 0.26</td>
<td>0.18 0.18 0.16 0.18</td>
</tr>
<tr>
<td><strong>Uncoated Double Glazing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5b 1/4 CLR CLR</td>
<td>0.78 SHGC</td>
<td>0.70 0.67 0.64 0.58 0.45 0.23 0.60</td>
<td>0.64</td>
<td>0.64</td>
<td>0.57 0.62</td>
<td>0.69 0.70 0.62 0.69</td>
</tr>
<tr>
<td>5h 1/4 GRY CLR</td>
<td>0.41 SHGC</td>
<td>0.47 0.44 0.42 0.37 0.29 0.16 0.39</td>
<td>0.43</td>
<td>0.43</td>
<td>0.38 0.42</td>
<td>0.36 0.37 0.33 0.36</td>
</tr>
<tr>
<td>5i 1/4 BLUGRN CLR</td>
<td>0.67 SHGC</td>
<td>0.50 0.47 0.45 0.40 0.32 0.17 0.43</td>
<td>0.46</td>
<td>0.46</td>
<td>0.41 0.44</td>
<td>0.60 0.60 0.54 0.59</td>
</tr>
<tr>
<td>5j 1/4 HI-P GRN CLR</td>
<td>0.59 SHGC</td>
<td>0.39 0.37 0.35 0.31 0.25 0.14 0.33</td>
<td>0.36</td>
<td>0.36</td>
<td>0.32 0.35</td>
<td>0.53 0.53 0.47 0.52</td>
</tr>
<tr>
<td><strong>Low-e Double Glazing, ε = 0.05 on surface 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25b 1/4 LE CLR</td>
<td>0.70 SHGC</td>
<td>0.37 0.36 0.34 0.31 0.24 0.13 0.32</td>
<td>0.34</td>
<td>0.34</td>
<td>0.30 0.33</td>
<td>0.62 0.63 0.56 0.62</td>
</tr>
<tr>
<td>25e 1/4 GRY W/LE CLR</td>
<td>0.35 SHGC</td>
<td>0.24 0.23 0.22 0.20 0.16 0.09 0.21</td>
<td>0.23</td>
<td>0.23</td>
<td>0.20 0.21</td>
<td>0.31 0.32 0.28 0.31</td>
</tr>
<tr>
<td>25g 1/4 HI-P GRN W/LE CLR</td>
<td>0.53 SHGC</td>
<td>0.27 0.26 0.25 0.23 0.18 0.11 0.23</td>
<td>0.26</td>
<td>0.25</td>
<td>0.22 0.24</td>
<td>0.47 0.48 0.42 0.47</td>
</tr>
</tbody>
</table>
How windows work

Thermal conductance, U-factor

Center-of-glass
- # panes
- gap width
- gas fill
- coating emittance

Whole window
+ Spacer
+ Frame

Insulated glass “IG” unit
- Spacer
- Gas fill
- Spacer

Code
How windows work

Thermal conductance, U-factor

Heat flow = (U-factor) * (window area) * (T_{outdoor} - T_{indoor})

\[
\text{Btu} \quad \frac{\text{hr}\cdot\text{ft}^2\cdot\text{°F}}{	ext{hr}}
\]
## Window U-factor

<table>
<thead>
<tr>
<th>Frame Type</th>
<th>Center of Glass</th>
<th>Edge of Glass</th>
<th>Aluminum Without Thermal Break</th>
<th>Aluminum with Thermal Break</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ID</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Single Glazing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1/8 in. glass</td>
<td>1.04</td>
<td>1.23</td>
<td>1.07</td>
</tr>
<tr>
<td>2</td>
<td>1/4 in. acrylic/polycarbonate</td>
<td>0.88</td>
<td>1.10</td>
<td>0.94</td>
</tr>
<tr>
<td>3</td>
<td>1/8 in. acrylic/polycarbonate</td>
<td>0.96</td>
<td>1.17</td>
<td>1.01</td>
</tr>
<tr>
<td><strong>Double Glazing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1/4 in. air space</td>
<td>0.55</td>
<td>0.81</td>
<td>0.64</td>
</tr>
<tr>
<td>5</td>
<td>1/2 in. air space</td>
<td>0.48</td>
<td>0.76</td>
<td>0.58</td>
</tr>
<tr>
<td>6</td>
<td>1/4 in. argon space</td>
<td>0.51</td>
<td>0.78</td>
<td>0.61</td>
</tr>
<tr>
<td>7</td>
<td>1/2 in. argon space</td>
<td>0.45</td>
<td>0.73</td>
<td>0.56</td>
</tr>
<tr>
<td><strong>Double Glazing, $e = 0.05$ on surface 2 or 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>1/4 in. air space</td>
<td>0.41</td>
<td>0.70</td>
<td>0.53</td>
</tr>
<tr>
<td>25</td>
<td>1/2 in. air space</td>
<td>0.30</td>
<td>0.61</td>
<td>0.45</td>
</tr>
<tr>
<td>26</td>
<td>1/4 in. argon space</td>
<td>0.33</td>
<td>0.64</td>
<td>0.47</td>
</tr>
<tr>
<td>27</td>
<td>1/2 in. argon space</td>
<td>0.25</td>
<td>0.57</td>
<td>0.41</td>
</tr>
</tbody>
</table>

Source: ASHRAE Handbook Fundamentals 2017
# How windows work

## Glass samples

### Monolithic glass

<table>
<thead>
<tr>
<th></th>
<th>SHGC</th>
<th>VLT</th>
<th>VLT/SHGC</th>
</tr>
</thead>
<tbody>
<tr>
<td>gray</td>
<td>0.58</td>
<td>0.44</td>
<td>0.76</td>
</tr>
<tr>
<td>blue</td>
<td>0.52</td>
<td>0.68</td>
<td>1.31</td>
</tr>
</tbody>
</table>

### Insulated glass

<table>
<thead>
<tr>
<th></th>
<th>SHGC</th>
<th>VLT</th>
<th>VLT/SHGC</th>
</tr>
</thead>
<tbody>
<tr>
<td>VE1-48</td>
<td>0.38</td>
<td>0.48</td>
<td>1.26</td>
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<tr>
<td>VNE1-53</td>
<td>0.23</td>
<td>0.49</td>
<td>2.13</td>
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<tr>
<td>VS1-20</td>
<td>0.23</td>
<td>0.18</td>
<td>0.78</td>
</tr>
</tbody>
</table>
Solar control priorities

1. Orientation
2. Fixed exterior shading
3. Operable exterior shading
4. High performance glazing
5. Interior shading
Solar control priorities

1. **Orientation**
2. Fixed exterior shading
3. Operable exterior shading
4. High performance glazing
5. Interior shading

**Challenging**

east & west orientation

**Better**

north & south
Solar control priorities

1. Orientation
2. Fixed exterior shading
3. Operable exterior shading
4. High performance glazing
5. Interior shading
Solar control priorities

1. Orientation
2. Fixed exterior shading
3. Operable exterior shading
4. High performance glazing
5. Interior shading

www.suncontrolers.com
Window Design Strategies

Solar control priorities
1. Orientation
2. Fixed exterior shading
3. Operable exterior shading
4. High performance glazing
5. Interior shading

Solar heat gain coefficient (SHGC)
Visible light transmittance (VLT)
Thermal conductance (U-factor)
Solar control priorities

1. Orientation
2. Fixed exterior shading
3. Operable exterior shading
4. High performance glazing
5. Interior shading
Additional options to reduce solar heat gain

- Fritted glass
- Laminations
- Retrofit films
- Dynamic glazing
Window Design Strategies

Additional options to reduce solar heat gain

- Fritted glass
- Laminations
- Retrofit films
- Dynamic glazing
Window Design Strategies

Additional options to reduce solar heat gain
- Fritted glass
- Laminations
- Retrofit films
- Dynamic glazing

Common applications
• Security
• Impact safety

Solar performance
• Spectrally selective coatings available
Additional options to reduce solar heat gain
- Fritted glass
- Laminations
- Retrofit films
- Dynamic glazing

**Common applications**
- Security
- Impact safety

**Solar performance**
- Spectrally selective coatings available

**Window Design Strategies**

Additional options to reduce solar heat gain

- Fritted glass
- Laminations
- Retrofit films
- Dynamic glazing

<table>
<thead>
<tr>
<th>VLT</th>
<th>SHGC</th>
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<tbody>
<tr>
<td>58%</td>
<td>0.41</td>
</tr>
<tr>
<td>40%</td>
<td>0.28</td>
</tr>
<tr>
<td>6%</td>
<td>0.11</td>
</tr>
<tr>
<td>1%</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Courtesy View Inc.
Window Design Strategies

Dynamic glass 4 tint states on a single facade

Tint 1  Tint 2  Tint 3  Tint 4

Courtesy View Inc.
Window Design Strategies

Dallas Fort Worth Airport. Courtesy View Inc.
Window Design Strategies

American Savings Bank Headquarters

11 stories
393,000 ft²
40,000 ft² dynamic glass (View)

Unobstructed views of ocean & mountains

No window coverings or shades / blinds in the building

Helps increase employee productivity and helps attract and retain talent within the bank

Architects : Leo A. Daly, Hi-archy
General Contractor: Nordic PCL
Section 3
Fenestration Requirements

- Checklists
- Residential requirements
- Commercial requirements
- Showing compliance
Checklists - Residential

RESIDENTIAL CHECKLIST
IECC 2015 with Hawaii Amendments

SCOPE
Detached one- and two-family dwellings and multiple single-family dwellings (townhouses) as well as Group R-2, R-3 and R-4 buildings three stories or less in height above grade plane.

The code applies to new construction, additions and alterations.

See a separate Commercial Checklist for high-rise residential and commercial buildings.

RESIDENTIAL COMPLIANCE OPTIONS

<table>
<thead>
<tr>
<th>Tropical Zone</th>
<th>Prescriptive</th>
<th>Simulated Performance Alternative</th>
<th>Energy Rating Index Compliance Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowed when:</td>
<td>Includes three options for walls and roof compliance:</td>
<td>Simulated energy performance analysis for heating, cooling and SHW. Proposed design must have annual energy cost less than or equal to energy cost of reference design.</td>
<td>Third-party Home Energy Rating System (HERS) calculation. Allows the designer to pick and choose from many efficiency options. Scores range from 100 to 0. The 100 score indicates compliance with the 2006 IECC. Each efficiency measure beyond 2006 lowers the score. A passing score for Climate Zone 1 is 52.</td>
</tr>
<tr>
<td>1. ≤50% air conditioned,</td>
<td>1. Prescriptive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. not heated, and</td>
<td>2. Total UA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. elevation &lt; 2,400 feet.</td>
<td>(typically with ResCheck software)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Points option</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(added by Hawaii amendment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>See Tropical Zone Checklist below</td>
<td>See Prescriptive Checklist below. See Points Option tables below.</td>
<td>See code Section R405</td>
<td>See code Section R406</td>
</tr>
</tbody>
</table>

CHECKLIST CONTENTS

<table>
<thead>
<tr>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical zone checklist</td>
</tr>
<tr>
<td>Prescriptive checklist</td>
</tr>
<tr>
<td>Additions and alterations checklist</td>
</tr>
<tr>
<td>Points option tables</td>
</tr>
</tbody>
</table>
1. Tropical Zone (NEW)
   - ≤50% air conditioned,
   - not heated, and
   - elevation < 2,400 feet
   - requires solar water heating

2. Prescriptive

3. Simulated performance alternative

4. Energy rating index, ERI (NEW)
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 dwelling unit is air conditioned.
2. The dwelling unit is not heated.
3. Solar, wind or other renewable energy source supplies not less than 90 percent of the energy for service water heating.
4. Glazing in dwelling units shall have a maximum solar heat gain coefficient as specified in Table R402.2.1.

Table R402.2.1. Window SHGC Requirements

<table>
<thead>
<tr>
<th>Projection Factor of overhang from base of average window sill</th>
<th>SHGC</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.30</td>
<td>0.25</td>
</tr>
<tr>
<td>0.30 - 0.50</td>
<td>0.40</td>
</tr>
<tr>
<td>≥ 0.50</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*b*Exception: North-facing windows with *pf* > 0.20 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.
6. Permanently installed lighting is in accordance with Section R404.
7. The 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.

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.

8. Roof surfaces have a minimum slope of 4 inch per foot of run. The finished roof does not have water accumulation areas.
9. 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.
10. Bedrooms with exterior walls facing two different direction have operable fenestration or exterior walls facing two different directions.
11. Interior doors to bedrooms are capable of being secured in the open position.
12. 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. [Eff 5/24/10; am and comp MAR 3 1 207] (Auth: HRS §107-29) (Imp: HRS §§107-24, 107-25)
Residential Fenestration
Tropical Zone Option

Overhang Projection Factor

PF = A/B

R401.2.1
Residential Fenestration
Tropical Zone Option

Maximum solar heat gain coefficient (SHGC)

<table>
<thead>
<tr>
<th>Large overhang</th>
<th>Medium overhang</th>
<th>Small overhang</th>
</tr>
</thead>
<tbody>
<tr>
<td>PF $\geq 0.5$</td>
<td>$0.30 \leq PF &lt; 0.50$</td>
<td>PF $&lt; 0.30$</td>
</tr>
<tr>
<td>No requirement</td>
<td>SHGC $\leq 0.40$</td>
<td>SHGC $\leq 0.25$</td>
</tr>
</tbody>
</table>

North windows: no requirement if PF $> 0.20$
Window examples
Dual-pane, low-e, solar control

Source: www.guardian.com

Low UV transmission is an extra benefit
Overhang size that allows clear glass to comply?

Clear glass complies in these examples

\[ PF \geq 0.5 \]
How about on the north side?

North-facing windows

Clear glass complies in these examples

\[ PF \geq 0.2 \]

R401.2.1
Solar heat gain coefficient (SHGC) ≤ 0.25
- Windows and skylights
- Area weighted average allowed

Exceptions
- Up to 15 ft² exempt
- Skylights can have SHGC ≤ 0.30
National Fenestration Rating Council (NFRC) Label
COMMERCIAL CHECKLIST
IECC 2015 with Hawaii Amendments

**SCOPE**

Commercial and high-rise residential buildings. More specifically, all buildings except detached one- and two-family dwellings and multiple single-family dwellings (townhouses) as well as Group R-2, R-3 and R-4 buildings three stories or less in height above grade plane.

The code applies to new construction, additions and alterations.

See a separate Residential Checklist for low-rise residential buildings.

**COMMERCIAL COMPLIANCE OPTIONS**

<table>
<thead>
<tr>
<th>Prescriptive</th>
<th>Total Building Performance Alternative</th>
<th>ASHRAE Standard 90.1-2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separate requirements for envelope, mechanical systems, water heating systems, lighting and electrical systems. Also includes “additional efficiency” requirements.</td>
<td>Simulated energy performance analysis for heating, cooling, lighting and SHW. Proposed design must have annual energy cost less than or equal to energy cost of reference design.</td>
<td>Includes both prescriptive and performance compliance options.</td>
</tr>
</tbody>
</table>

See Prescriptive Checklist below  
See code Section C407  
See separate standard, available from www.ashrae.org

**CHECKLIST CONTENTS**

<table>
<thead>
<tr>
<th>Checklist Item</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Envelope</td>
<td>2</td>
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<tr>
<td>Mechanical system</td>
<td>5</td>
</tr>
<tr>
<td>Service water heating</td>
<td>8</td>
</tr>
<tr>
<td>Lighting and electrical</td>
<td>10</td>
</tr>
<tr>
<td>Additional efficiency</td>
<td>14</td>
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<tr>
<td>Additions</td>
<td>16</td>
</tr>
<tr>
<td>Alterations</td>
<td>18</td>
</tr>
</tbody>
</table>
Commercial Fenestration Compliance Options

- Prescriptive requirements
  - Windows
    - Maximum area, U-factor & SHGC
  - Skylights
    - Maximum area, U-factor & SHGC
    - Minimum area

- Total Building Performance

- ASHRAE Standard 90.1-2013
Commercial Fenestration - Prescriptive

Maximum Area

Window area \( \leq 30\% \) of gross wall area
Up to 40\% with daylighting controls

Skylight area \( \leq 3\% \) of gross roof area
Up to 5\% with daylighting controls

Otherwise, use Total Building Performance compliance option
Commercial window area limit example

Is window area ≤ 30% gross wall area?

Window area = 280 ft$^2$

Gross wall area = \((30 + 40 + 30 + 40) \times 12\) = 1,680 ft$^2$

\% Window area = \(\frac{280}{1,680} = 17\%\)  OK
### Commercial Fenestration - Prescriptive Window SHGC

#### Maximum solar heat gain coefficient (SHGC)

<table>
<thead>
<tr>
<th>E/S/W</th>
<th>Large overhang</th>
<th>Medium overhang</th>
<th>Small overhang</th>
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</thead>
<tbody>
<tr>
<td>PF ≥ 0.5</td>
<td>SHGC ≤ 0.40</td>
<td>0.20 ≤ PF &lt; 0.50</td>
<td>SHGC ≤ 0.25</td>
</tr>
<tr>
<td>0.20 ≤ PF &lt; 0.50</td>
<td>SHGC ≤ 0.30</td>
<td>PF &lt; 0.20</td>
<td></td>
</tr>
<tr>
<td>PF &lt; 0.20</td>
<td>SHGC ≤ 0.37</td>
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<td></td>
</tr>
<tr>
<td>North</td>
<td>SHGC ≤ 0.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SHGC ≤ 0.37</td>
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<tr>
<td></td>
<td>SHGC ≤ 0.33</td>
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<td></td>
</tr>
</tbody>
</table>

Area-weighted average SHGC allowed by Hawaii amendment

---

C402.4
Commercial Fenestration - Prescriptive
Window U-factor

Maximum U-factor
• U-0.50 fixed
• U-0.65 operable
• U-1.10 doors

Area-weighted average U-factor allowed
Commercial Fenestration - Prescriptive Skylight SHGC & U-factor

SHGC $\leq 0.35$

(or $\leq 0.60$ with daylighting controls)

U-factor $\leq 0.75$

(or U-0.90 with daylighting controls)
Commercial Fenestration - Prescriptive
Skylight – Minimum Area

For spaces under a roof where
• Floor area > 2,500 ft² and
• Ceiling height > 15 ft
Commercial Fenestration - Prescriptive
Skylight – Minimum Area

For spaces under a roof where
• Area > 2,500 ft$^2$ and
• Ceiling height > 15 ft

≥50% of floor area must be
daylighted by skylights

and

Minimum skylight area
1. 3% or roof, or
2. 1% effective aperture

Several exceptions apply

Space types
• office
• lobby
• atrium
• concourse
• corridor
• storage space
• gymnasium/exercise center
• convention center
• automotive service area
• manufacturing
• nonrefrigerated warehouse
• retail store
• distribution/sorting area
• transportation depot
• workshop
Minimum skylight area example

When
1. Space floor area > 2500 ft²
2. Ceiling height > 15 ft

Requirements
- Daylighted area ≥ 50% of floor area
- Skylight area ≥ 3% of daylighted area
Information required on construction documents
(Also shown on checklists)

1. Insulation materials and their R-values.
2. Fenestration \( U \)-factors and solar heat gain coefficients (SHGC).
3. Area-weighted \( U \)-factor and solar heat gain coefficients (SHGC) calculations.

Excerpt from Sections R103.2 and C103.2
Showing Compliance
Residential Certification

COUNTY OF [COUNTY’S ENERGY CODE NAME]

To the best of my knowledge, this project’s design substantially conforms to the Residential Provisions of [COUNTY’S ENERGY CODE NAME] (2015 IECC as amended).

COMPLIANCE METHOD
- Tropical Zone, R401.2.1
- Prescriptive, R402
  - Roof and Wall
    - Insulation R-value, Table R401.1.2
    - Construction U-factor, Table R402.1.4
    - Total UA, R402.1.5
  - Points Option: R407
- Simulated Performance Alternative, R405
- Energy Rating Index Compliance Alternative, R406

<table>
<thead>
<tr>
<th>INFORMATION IN CONSTRUCTION DOCUMENTS</th>
<th>Yes</th>
<th>N/A</th>
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<tbody>
<tr>
<td>Envelope</td>
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<tr>
<td>Roof insulation R-value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof insulation type and location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof membrane solar reflectance and thermal emittance</td>
<td></td>
<td></td>
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<tr>
<td>Wall insulation R-value</td>
<td></td>
<td></td>
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<tr>
<td>Wall insulation type and location</td>
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<tr>
<td>Window and skylight SH0C</td>
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<tr>
<td>Air leakage testing requirement</td>
<td></td>
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<td>Air Conditioning</td>
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<td>Air conditioning equipment capacity and efficiency</td>
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<td>Programmable thermostat</td>
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<tr>
<td>Duct insulation R-value</td>
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<td>Duct leakage testing requirement</td>
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<td>Electrical</td>
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<td>Lighting fixture locations</td>
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<td>Lamp type</td>
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<td>Ceiling fans</td>
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<tr>
<td>Whole-house fan</td>
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<td></td>
</tr>
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</table>

NOTES

SIGNATURE:

DATE:

NAME:

TITLE:

LICENSE NO.:
**Showing Compliance Residential Certification**

**COMPLIANCE METHOD**
- Tropical Zone. R401.2.1
- Prescriptive. R402
  - Roof and Wall
    - Insulation R-value. Table R401.1.2
    - Construction U-factor. Table R402.1.4
    - Total UA. R402.1.5
    - Points Option. R407
- Simulated Performance Alternative. R405
- Energy Rating Index Compliance Alternative. R406

**INFORMATION IN CONSTRUCTION DOCUMENTS**

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<th>Envelope</th>
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<tr>
<td>Roof insulation R-value</td>
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<tr>
<td>Roof insulation type and location</td>
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</tr>
<tr>
<td>Roof membrane solar reflectance and thermal emittance</td>
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</tr>
<tr>
<td>Wall insulation R-value</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Wall insulation type and location</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td><strong>Window and skylight SHGC</strong></td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Air leakage testing requirement</td>
<td>☐</td>
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</tbody>
</table>
COUNTY OF MAUI
MAUI COUNTY CODE, CHAPTER 16.16B ENERGY CODE
RESIDENTIAL PROVISIONS

<table>
<thead>
<tr>
<th>COMPLIANCE METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check applicable method</td>
</tr>
<tr>
<td>R401.2(1) R401.3 through R404 (Prescriptive)</td>
</tr>
<tr>
<td>R401.2(2) R405, R401 through R404 labeled Mandatory (Simulated Performance Alternative)</td>
</tr>
<tr>
<td>R401.2(3) R406 (Energy Rating Index Compliance Alternative)</td>
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<tr>
<td>R401.2(4) R401.2.1 (Tropical Zone)</td>
</tr>
<tr>
<td>R102.1 (Alternative)</td>
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</tbody>
</table>

To the best of my knowledge, this project’s design substantially conforms to the Energy Code.

Signature: ___________________________ Date: ________________

Name: _______________________________

Title: _______________________________

License No.: _________________________
Showing Compliance
Commercial Certification

**COUNTY OF [COUNTY'S ENERGY CODE NAME]**

To the best of my knowledge, this project’s design substantially conforms to the [CODE NAME] (2015 IECC as amended) for building envelope components (Section C402).

**COMPLIANCE METHOD**
- ☐ 2015 IECC as amended, Mandatory & Prescriptive
- ☐ 2015 IECC as amended, Mandatory & Total Building Performance
- ☐ ASHRAE Standard 90.1-2013. Mandatory & Prescriptive
- ☐ ASHRAE Standard 90.1-2013. Mandatory & Energy Cost Budget Method

**INFORMATION IN CONSTRUCTION DOCUMENTS**

<table>
<thead>
<tr>
<th>Item</th>
<th>Yes</th>
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<td>Roof insulation type and location</td>
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<td>Roof membrane solar reflectance and thermal emittance</td>
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<tr>
<td>Wall insulation R-value</td>
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<td>Wall insulation type and location</td>
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<tr>
<td>Window SHGC</td>
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<td>Window U-factor</td>
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<td>Skylight SHGC</td>
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<tr>
<td>Skylight U-factor</td>
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</tr>
</tbody>
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**NOTES**

**SIGNATURE:**

**DATE:**

**NAME:**

**TITLE:**

**LICENSE NO.:**
Showing Compliance
Commercial Certification

COMPLIANCE METHOD

☐ 2015 IECC as amended. Mandatory & Prescriptive
☐ 2015 IECC as amended. Mandatory & Total Building Performance
☐ ASHRAE Standard 90.1-2013. Mandatory & Prescriptive
☐ ASHRAE Standard 90.1-2013. Mandatory & Energy Cost Budget Method

INFORMATION IN CONSTRUCTION DOCUMENTS

- Roof insulation R-value
- Roof insulation type and location
- Roof membrane solar reflectance and thermal emittance
- Wall insulation R-value
- Wall insulation type and location
- Window SHGC
- Window U-factor
- Skylight SHGC
- Skylight U-factor

COUNTY OF [COUNTY NAME]
COUNTY’S ENERGY CODE NAME
To the best of my knowledge, this project’s design substantially conforms to the [CODE NAME] 2015 IECC as amended for building envelope components (Section 408)
## Compliance Method

Check applicable method

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>☐</td>
<td>C401.2(1) ANSI/ASHRAE/IESNA 90.1</td>
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<tr>
<td>☐</td>
<td>C401.2(2) Sections C402 through C406</td>
</tr>
<tr>
<td>☐</td>
<td>C401.2(3) Sections C402.5, C403.2, C404, C405.2, C405.3, C405.4, C405.6 &amp; C407</td>
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<tr>
<td>☐</td>
<td>C102.1 Alternative</td>
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</table>

To the best of my knowledge, this project’s design substantially conforms to the Energy Code.

Signature: ___________________________ Date: ____________

Name: _______________________________

Title: _______________________________

License No.: ________________________
One more thing

Solar control vs. transparency

- Kakaako Mauka Area Rules
  - VLT ≥ 70% on ground floor
  - VLT ≥ 50% other floors

(k) Windows:
(1) Highly-reflective, mirrored, and opaque window glazing are prohibited;
(2) Window glazing shall be transparent with clear or limited UV tint so as to provide views out of and into the building. Visible light transmission level of windows on the ground floor shall be seventy per cent or greater and on all other floors the visible light transmission level shall be fifty per cent or greater;

Fenestration compliance quiz

1. Does a non-AC home need to meet window requirements?
2. Can a home with 90% glass walls comply?
3. Can an office with 90% glass walls comply?
4. Can a retail storefront use clear glass?
5. Is a new gym without AC required to have skylights?
6. Does an auto repair shop without AC have to meet window requirements?
Section 4
Opaque Envelope Design

- Heat transfer
- Opaque envelope options
  - Insulation
  - Radiant barriers
  - Cool roofs
  - Cool walls
Opaque Envelope Heat Transfer

- Conduction
- Convection
- Shortwave radiation
- Longwave radiation

Temperature labels:
- $T_{\text{outside air}}$
- $T_{\text{outside surface}}$
- $T_{\text{sky}}$
- $T_{\text{ground}}$
- $T_{\text{indoor air}}$
- $T_{\text{inside surface}}$
- $T_{\text{indoor surfaces}}$
Opaque Envelope Heat Transfer

Short-wave solar radiation

Long-wave infrared radiation
Opaque Envelope Heat Transfer

Longwave Infrared Radiation

\[ W = \varepsilon \sigma T^4 \]

\[ q_{net\ 1 \ to \ 2} = \frac{\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} \]

\( W \) = emissive power, Btu/hr·ft²
\( \varepsilon \) = thermal emittance of material
\( \sigma = 0.1712 \times 10^{-8} \) (Btu/h·ft²·°R⁴)
\( T \) = temperature, °R

\( q_{net\ 1 \ to \ 2} \) = net radiant heat transfer between two planar surfaces (Btu/h·ft²)

\( \varepsilon = \) Radiation emitted by a given material
\[ \frac{\text{Radiation emitted by a black body at the same temperature}}{\varepsilon} \]

\( \varepsilon = 0.8 - 0.9 \) typical
\( \varepsilon < 0.1 \) for “low-e” surfaces, polished metal
Opaque Envelope Heat Transfer

Heat transfer within an assembly

Solid material

\[ T_{\text{outer surface}} \quad T_{\text{inner surface}} \]

Conduction

Assembly with air gap

Conduction
Convection
Longwave radiation
Opaque Envelope Heat Transfer

Heat transfer at interior and exterior surfaces

- Convection
- Shortwave radiation
- Longwave radiation

Temperature variables:
- $T_{\text{outside air}}$
- $T_{\text{outside surface}}$
- $T_{\text{sky}}$
- $T_{\text{ground}}$
- $T_{\text{indoor air}}$
- $T_{\text{inside surface}}$
- $T_{\text{indoor surfaces}}$
Opaque Envelope Heat Transfer

Heat transfer at interior and exterior surfaces

Shortwave radiation factors
- Sun position
- Sky condition
- Solar reflectance

Shortwave radiation
Opaque Envelope Heat Transfer

Heat transfer at interior and exterior surfaces

Convection factors
- Air temperature
- Surface temperatures
- Air speed
- Surface roughness
Opaque Envelope Heat Transfer

Heat transfer at interior and exterior surfaces

Longwave radiation factors
- Surface and sky temperatures
- View factors
- Infrared (thermal) emittance

$T_{\text{outside surface}}$  $T_{\text{inside surface}}$

$T_{\text{sky}}$  $T_{\text{indoor surfaces}}$

$T_{\text{ground}}$

Longwave radiation
Opaque Envelope Heat Transfer

- Conduction
- Convection
- Shortwave radiation
- Longwave radiation

\[ T_{\text{outside air}} \]
\[ T_{\text{outside surface}} \]
\[ T_{\text{sky}} \]
\[ T_{\text{ground}} \]
\[ T_{\text{indoor air}} \]
\[ T_{\text{inside surface}} \]
\[ T_{\text{indoor surfaces}} \]
Opaque Envelope Heat Transfer

• Simplified assembly properties
  - Thermal transmittance (U-factor)
  - Solar reflectance, exterior surface
  - Infrared emittance, exterior and interior surfaces
Opaque Envelope Options

Opaque envelope options

• Insulation
• Radiant barriers
• Cool roofs
• Cool walls
## Opaque Envelope Options

<table>
<thead>
<tr>
<th>Insulation Materials</th>
<th>Typical R-value per inch of thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Batt</strong> - fiberglass, cellulose, cotton</td>
<td>R-3 – R-4</td>
</tr>
<tr>
<td><strong>Loose fill</strong> - fiberglass, cellulose, cotton</td>
<td>R-3 – R-4</td>
</tr>
<tr>
<td><strong>Foam board</strong> - polyisocyanurate</td>
<td>R-6</td>
</tr>
<tr>
<td><strong>Foam board</strong> - extruded polystyrene</td>
<td>R-5</td>
</tr>
<tr>
<td><strong>Foam board</strong> - expanded polystyrene</td>
<td>R-4</td>
</tr>
<tr>
<td><strong>Spray foam</strong> - polyurethane</td>
<td>R-6</td>
</tr>
<tr>
<td><strong>Spray foam</strong> - “Icynene”</td>
<td>R-3.6</td>
</tr>
<tr>
<td><strong>Spray foam</strong> – soy based</td>
<td>R-3.6</td>
</tr>
<tr>
<td><strong>Aerogel</strong></td>
<td>Up to R-20</td>
</tr>
</tbody>
</table>
# Opaque Envelope Options

## Thermal Bridging – Metal Framing

<table>
<thead>
<tr>
<th>Assembly</th>
<th>Insulation R-value</th>
<th>Correction Factor</th>
<th>Effective R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x4, 16 in. spacing</td>
<td>11</td>
<td>0.50</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>0.46</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.43</td>
<td>6.4</td>
</tr>
<tr>
<td>2x4, 24 in. spacing</td>
<td>11</td>
<td>0.60</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>0.55</td>
<td>7.2</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.52</td>
<td>7.8</td>
</tr>
<tr>
<td>2x6, 16 in. spacing</td>
<td>19</td>
<td>0.37</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>0.35</td>
<td>7.4</td>
</tr>
<tr>
<td>2x6, 24 in. spacing</td>
<td>19</td>
<td>0.45</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>0.43</td>
<td>9.0</td>
</tr>
</tbody>
</table>

Source: ASHRAE Handbook Fundamentals 2017
Opaque Envelope Options

Radiant Barrier

Hot roof

Warm ceiling

Cooler ceiling

$q_{net \ 1 \ to \ 2} = \frac{\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$

With radiant barrier (low-e surface) $\varepsilon < 0.05$
Opaque Envelope Options

Cool Roof

• High solar reflectance
• High infrared emittance

Reflected shortwave radiation

Convected heat

Emitted longwave radiation

Conducted heat

Roof

Indoors
Opaque Envelope Options

Roof Temperature Examples

Sacramento, CA - 89°F ambient

EPDM single-ply
173°F

Built up roof with aggregate
159°F

Built up roof with capsheet
158°F

Courtesy Dan Varvais, Applied Polymer Systems
Opaque Envelope Options

Cool Roof

Types
• Single ply plastic
• Metal
• Liquid applied
• Tile (clay or concrete)
• Composite shingle

http://coolroofhawaii.com
http://www.whirlwindsteel.com
## Opaque Envelope Options

<table>
<thead>
<tr>
<th>Material</th>
<th>Solar Reflectance</th>
<th>Emittance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt shingles</td>
<td>5% – 30%</td>
<td>0.91</td>
</tr>
<tr>
<td>Liquid coating - white</td>
<td>65% - 78%</td>
<td>0.86 – 0.91</td>
</tr>
<tr>
<td>Liquid coating - silver</td>
<td>54%</td>
<td>0.42</td>
</tr>
<tr>
<td>Painted metal – white</td>
<td>60% - 67%</td>
<td>~0.90</td>
</tr>
<tr>
<td>Painted metal – other</td>
<td>8% - 66%</td>
<td>~0.90</td>
</tr>
<tr>
<td>Concrete tile – unpainted</td>
<td>25%</td>
<td>0.90</td>
</tr>
<tr>
<td>Concrete tile – white</td>
<td>73%</td>
<td>0.90</td>
</tr>
<tr>
<td>Single ply – grey</td>
<td>23%</td>
<td>~0.90</td>
</tr>
<tr>
<td>Single ply – white</td>
<td>80%</td>
<td>~0.90</td>
</tr>
<tr>
<td>Unpainted galvanized steel</td>
<td>61%</td>
<td>0.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRRC PROD. ID</th>
<th>MANUFACTURER: BRAND MODEL</th>
<th>PRODUCT TYPE</th>
<th>COLOR</th>
<th>SOLAR REFLECTANCE</th>
<th>THERMAL EMITTANCE</th>
<th>SRI</th>
<th>MORE INFO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>initial 3 year</td>
<td>initial 3 year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0808-0001</td>
<td>Burkeline Roofing: M-558 CSPE White</td>
<td>Membrane: Single Ply Thermoplastic and Thermoset Roofing</td>
<td>Bright White</td>
<td>0.85   0.71</td>
<td>0.88 0.87</td>
<td>104 87</td>
<td>+</td>
</tr>
<tr>
<td>0628-0011</td>
<td>Carlisle Construction Materials Incorporated: Spectro-Weld TPO White</td>
<td>Membrane: Single Ply Thermoplastic and Thermoset Roofing</td>
<td>Bright White</td>
<td>0.88   0.75</td>
<td>0.89 0.90</td>
<td>111 93</td>
<td>+</td>
</tr>
<tr>
<td>0628-0017</td>
<td>Carlisle Construction Materials Incorporated: Sure-Flex KEE HP Grey</td>
<td>Membrane: Single Ply Thermoplastic and Thermoset Roofing</td>
<td>Grey</td>
<td>0.57   0.50</td>
<td>0.88 0.85</td>
<td>67 57</td>
<td>+</td>
</tr>
<tr>
<td>0628-0016</td>
<td>Carlisle Construction Materials Incorporated: Sure-Flex KEE HP Tan</td>
<td>Membrane: Single Ply Thermoplastic and Thermoset Roofing</td>
<td>Tan</td>
<td>0.74   0.63</td>
<td>0.88 0.84</td>
<td>91 75</td>
<td>+</td>
</tr>
<tr>
<td>0628-0015</td>
<td>Carlisle Construction Materials Incorporated: Sure-Flex KEE HP White</td>
<td>Membrane: Single Ply Thermoplastic and Thermoset Roofing</td>
<td>Bright White</td>
<td>0.82   0.71</td>
<td>0.89 0.84</td>
<td>103 86</td>
<td>+</td>
</tr>
</tbody>
</table>

http://www.coolroofs.org/products/search.php
CRRC Product Label Example

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>Weathered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Reflectance</td>
<td>0.88</td>
<td>0.68 3 year aged</td>
</tr>
<tr>
<td>Thermal Emittance</td>
<td>0.87</td>
<td>0.89 3 year aged</td>
</tr>
</tbody>
</table>

Rated Product ID Number: 0001
Licensed Seller ID Number: 0896
Classification: Production Line

Cool Roof Rating Council ratings are determined for a fixed set of conditions, and may not be appropriate for determining seasonal energy performance. The actual effect of solar reflectance and thermal emittance on building performance may vary.

Manufacturer of product stipulates that these ratings were determined in accordance with the applicable Cool Roof Rating Council procedures.
Opaque Envelope Options

Infrared reflecting pigments

- IR-reflecting black: 28%
- Standard black: 6%
- White: 85%
Opaque Envelope Options

Infrared reflecting pigments

<table>
<thead>
<tr>
<th>Color</th>
<th>Reflectance (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>black</td>
<td>R=0.41</td>
</tr>
<tr>
<td>blue</td>
<td>R=0.44</td>
</tr>
<tr>
<td>gray</td>
<td>R=0.44</td>
</tr>
<tr>
<td>terracotta</td>
<td>R=0.48</td>
</tr>
<tr>
<td>green</td>
<td>R=0.46</td>
</tr>
<tr>
<td>chocolate</td>
<td>R=0.41</td>
</tr>
<tr>
<td></td>
<td>R=0.04</td>
</tr>
<tr>
<td></td>
<td>R=0.18</td>
</tr>
<tr>
<td></td>
<td>R=0.21</td>
</tr>
<tr>
<td></td>
<td>R=0.33</td>
</tr>
<tr>
<td></td>
<td>R=0.17</td>
</tr>
<tr>
<td></td>
<td>R=0.12</td>
</tr>
</tbody>
</table>
Opaque Envelope Options

Asphalt shingle examples

Opaque Envelope Options

Asphalt shingle examples

Opaque Envelope Options

Metal shingle examples

0.37

0.33

0.26

0.32

Opaque Envelope Options

Cool Walls

- Light color paint
- Infrared-reflective paint
- Pigments with fluorescence
  - Effective solar reflectance > solar reflectance

https://heatisland.lbl.gov/projects/cool-walls
Opaque Envelope Options

Fluorescence

SR = solar reflectance
ESR = effective solar reflectance

https://heatisland.lbl.gov/projects/cool-walls
Opaque Envelope Options

Summary

Reducing heat gain
• Insulation
• Thermal bridge mitigation
• Radiant barriers
• Solar reflectance
• Infrared emittance
I want to keep my home cool. Do I want **high** or **low** infrared emittance?

1. On top of the roof
2. Under the roof
3. On the exterior wall surface
4. On the interior wall surface
Section 5
Opaque Envelope Requirements

• Residential
• Commercial
• Compliance documentation
1. **Tropical Zone (NEW)**
   - ≤50% air conditioned,
   - not heated, and
   - elevation < 2,400 feet
   - requires solar water heating

2. **Prescriptive**
   Wall and roof options:
   1. Prescriptive
   2. Total UA
   3. Points option (Hawaii amendment)

3. **Simulated performance alternative**

4. **Energy rating index, ERI (NEW)**
Residential Opaque Envelope
Tropical Zone Option

Roof options

1. R-19 roof insulation
2. Cool roof + R-13 insulation
3. Points option (R407)

If there is an attic

- Vented if attic above insulation
- Unvented if attic below insulation
Natural ventilation requirements

Operable windows

- Area ≥ 14% of floor area

Bedrooms

- Interior doors can be secured open
- Openings on two different sides if exterior walls face two different directions

Ceiling fans or rough-ins in

- Bedrooms
- Largest space that is not a bedroom

Jalousie windows

- Air infiltration rate ≤ 1.2 cfm/ft²
Residential Opaque Envelope
Tropical Zone Option

Wall requirements
None
## Residential Opaque Envelope
### Prescriptive Option

<table>
<thead>
<tr>
<th>Material</th>
<th>R-value (hr-ft²·°F/Btu)</th>
<th>U-factor (Btu/hr-ft²·°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling</td>
<td>R-30</td>
<td>0.035</td>
</tr>
<tr>
<td>Wood frame wall</td>
<td>R-13</td>
<td>0.084</td>
</tr>
<tr>
<td>Mass wall</td>
<td>R-3 – exterior R-4 – interior</td>
<td>0.197</td>
</tr>
<tr>
<td>Floor</td>
<td>R-13</td>
<td>0.064</td>
</tr>
<tr>
<td>Basement wall</td>
<td>0</td>
<td>0.360</td>
</tr>
<tr>
<td>Slab on grade</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>Crawl space wall</td>
<td>0</td>
<td>0.477</td>
</tr>
</tbody>
</table>

**R-0 (Kauai and Maui)**

**R-0 (Kauai) with:**
- Reflectance ≥ 0.64 or
- Overhang PF ≥ 0.3

Table R402.1.2
## Residential Opaque Envelope
### Prescriptive Option

<table>
<thead>
<tr>
<th></th>
<th>Insulation R-value (hr-ft²-°F/Btu)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Steel frame wall,</strong></td>
<td></td>
</tr>
<tr>
<td>16 in. o.c.</td>
<td>R-0 + 9.3</td>
</tr>
<tr>
<td></td>
<td>R-13 + 4.2</td>
</tr>
<tr>
<td></td>
<td>R-15 + 3.8</td>
</tr>
<tr>
<td></td>
<td>R-19 + 2.1</td>
</tr>
<tr>
<td></td>
<td>R-21 + 2.8</td>
</tr>
<tr>
<td><strong>Steel frame wall,</strong></td>
<td></td>
</tr>
<tr>
<td>24 in. o.c.</td>
<td>R-0 + 9.3</td>
</tr>
<tr>
<td></td>
<td>R-13 + 3.0</td>
</tr>
<tr>
<td></td>
<td>R-15 + 2.4</td>
</tr>
<tr>
<td><strong>Steel truss ceiling</strong></td>
<td>R-38</td>
</tr>
<tr>
<td></td>
<td>R-30 + 3</td>
</tr>
<tr>
<td></td>
<td>R-26 + 5</td>
</tr>
<tr>
<td><strong>Steel joist ceiling</strong></td>
<td>R-38</td>
</tr>
<tr>
<td></td>
<td>R-49 if framing &gt; 2x8</td>
</tr>
</tbody>
</table>
Residential Opaque Envelope
Prescriptive Option

Wood-frame Ceilings

Some R-30 insulation options

- 10 in. batt
- ~10 in. blown-in
- ~8 in. open-cell spray foam
- ~5 in. closed-cell spray foam

Or use the points option for compliance
Residential Opaque Envelope
Prescriptive Option

Table R402.1.2

Wood-frame Walls

Some R-13 insulation options
• 3.5 in. batt
• 3.5 in. blown-in
• 3.5 in. open-cell spray foam
• ~2 in. closed-cell spray foam
Residential Opaque Envelope
Prescriptive Option

Table R402.1.2

Mass Walls  Kauai amendment, next slide

- **R-3 exterior**
  - ≥ 0.50 in. polyisocyanurate
  - ≥ 0.60 in. polystyrene

- **R-4 interior**
  - ≥ 0.67 in. polyisocyanurate
  - ≥ 0.80 in. polystyrene

- **U-factor ≤ 0.197**
  - ≥ R-4 in wood furring
  - ≥ R-11 in metal furring
Residential Opaque Envelope
Prescriptive Option

Mass Walls  Kauai Amendment

Reflectance  ≥ 0.64

Overhang PF  ≥ 0.3
Residential Opaque Envelope
Prescriptive Option

Table R402.1.2

Metal-frame walls

<table>
<thead>
<tr>
<th>Framing 16 in. o.c.</th>
<th>Framing 24 in. o.c.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-0 + 9.3</td>
<td>R-0 + 9.3</td>
</tr>
<tr>
<td>R-13 + 4.2</td>
<td>R-13 + 3.0</td>
</tr>
<tr>
<td>R-15 + 3.8</td>
<td>R-15 + 2.4</td>
</tr>
</tbody>
</table>

Rigid foam board thickness

<table>
<thead>
<tr>
<th>R-value</th>
<th>Extruded Polystyrene (R-5/in.)</th>
<th>Polyisocyanurate (R-6/in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4</td>
<td>≥ 0.48 in.</td>
<td>≥ 0.40 in.</td>
</tr>
<tr>
<td>3.0</td>
<td>≥ 0.60 in.</td>
<td>≥ 0.50 in.</td>
</tr>
<tr>
<td>3.8</td>
<td>≥ 0.76 in.</td>
<td>≥ 0.63 in.</td>
</tr>
<tr>
<td>4.2</td>
<td>≥ 0.84 in.</td>
<td>≥ 0.70 in.</td>
</tr>
<tr>
<td>9.3</td>
<td>≥ 1.86 in.</td>
<td>≥ 1.55 in.</td>
</tr>
</tbody>
</table>

Or use the points option for compliance
Residential Opaque Envelope
Total UA Option

- Calculate total U-factor x Area for walls and roof
- Typically use REScheck software
  - Desktop or Web version
  - https://energycode.pnl.gov/REScheckWeb
### Ceilings / Skylights (1 assembly)

<table>
<thead>
<tr>
<th>Ceilings</th>
<th>Assembly</th>
<th>Gross Area</th>
<th>Cavity Insulation R-Value</th>
<th>Continuous Insulation R-Value</th>
<th>U-Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling</td>
<td>Flat Ceiling or Scissor Truss</td>
<td>1500</td>
<td>38</td>
<td>0</td>
<td>0.03</td>
</tr>
</tbody>
</table>

### Walls / Windows / Doors (1 assembly)

<table>
<thead>
<tr>
<th>Walls</th>
<th>Assembly</th>
<th>Gross Area</th>
<th>Cavity Insulation R-Value</th>
<th>Continuous Insulation R-Value</th>
<th>U-Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall</td>
<td>Steel Frame, 16&quot; o.c.</td>
<td>1600</td>
<td>19</td>
<td>5</td>
<td>0.101</td>
</tr>
</tbody>
</table>
Compliance Certificate

Project: Tropical house

Energy Code: 2015 IECC
Location: Honolulu, Hawaii
Construction Type: Single-family
Project Type: New Construction
Conditioned Floor Area: 1,500 ft²
Climate Zone: 1 (0 HDD)

Construction Site: Owner/Agent: Designer/Contractor:

Compliance: Passes using UA trade-off

Compliance: 15.0% Better Than Code
Maximum UA: 187
Your UA: 159
Maximum SHGC: 0.25
Your SHGC: 0.00

The % Better or Worse Than Code index reflects how close to compliance the house is based on code trade-off rules. It DOES NOT provide an estimate of energy use or cost relative to a minimum-code home.

Envelope Assemblies

<table>
<thead>
<tr>
<th>Assembly</th>
<th>Gross Area</th>
<th>Cavity R-Value</th>
<th>Cont. R-Value</th>
<th>U-Factor</th>
<th>UA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling: Flat Ceiling or Scissor Truss</td>
<td>1.500</td>
<td>38.0</td>
<td>0.0</td>
<td>0.030</td>
<td>45</td>
</tr>
<tr>
<td>Wall: Steel Frame, 16&quot; o.c.</td>
<td>1.600</td>
<td>19.0</td>
<td>5.0</td>
<td>0.071</td>
<td>114</td>
</tr>
</tbody>
</table>

Compliance Statement: The proposed building design described here is consistent with the building plans, specifications, and other calculations submitted with the permit application. The proposed building has been designed to meet the 2015 IECC requirements in REScheck Version: REScheck-Web and to comply with the mandatory requirements listed in the REScheck Inspection Checklist.

Name - Title: Signature: Date:

Project Title: Tropical house
Report date: 04/08/18
Data filename:
Residential Opaque Envelope Points Option

- Total points ≥ 0
  - Roof and walls, or
  - Roof alone and wall alone
- Options for credit
  - Insulation
  - Cool roof
  - Radiant barrier
  - Wall reflectance
  - More efficient lighting
  - Efficient appliances
  - Wall shading
  - Ductless AC
  - High efficiency AC
  - No AC
  - Small dwelling
  - Energy Star fans
  - Solar electric

Reasons to use the Points Option
1. Want <R-30 roof insulation
2. Have metal-framed walls and don’t want to add foam board insulation
## Points Option - Wood Framed Walls

<table>
<thead>
<tr>
<th>Measure</th>
<th>Standard Home Points</th>
<th>Tropical Zone Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-13 cavity wall insulation</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>R-19 roof insulation</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>R-19 roof insulation + cool roof membrane(^1) or radiant barrier(^3)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>R-19 roof insulation + attic venting(^2)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>R-30 roof insulation</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>R-13 wall insulation + high reflectance walls(^4)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>R-13 wall + 90% high efficacy lighting and Energy Star appliances(^5)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>R-13 wall insulation + exterior shading wpf=0.3(^6)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Ductless air conditioner(^7)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1.071 X Federal minimum SEER for air conditioner</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1.142 X Federal minimum SEER for air conditioner</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>No air conditioning installed</td>
<td>NA</td>
<td>2</td>
</tr>
<tr>
<td>House floor area ≤ 1,000 ft(^2)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>House floor area ≥ 2,500 ft(^2)</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>Energy Star fans(^8)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Install 1 kW or greater of solar electric</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
# Points Option - Metal Framed Walls

<table>
<thead>
<tr>
<th>Measure</th>
<th>Standard Home Points</th>
<th>Tropical Zone Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-13 + R-3 wall insulation</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>R-13 cavity wall insulation + R-0</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>R-13 wall insulation + high reflectance walls⁴</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>R-13 wall insulation + 90% high efficacy lighting and Energy Star Appliances⁵</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>R-13 wall insulation + exterior shading wpf=0.3⁶</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>R-30 roof insulation</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>R-19 roof insulation</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>R-19 + cool roof membrane¹ or radiant barrier³</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>R-19 roof insulation + attic venting²</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Ductless air conditioner⁷</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1.071 X Federal minimum SEER for air conditioner</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1.142 X Federal minimum SEER for air conditioner</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>No air conditioning installed</td>
<td>NA</td>
<td>2</td>
</tr>
<tr>
<td>House floor area ≤ 1,000 ft²</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>House floor area ≥ 2,500 ft²</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>Energy Star Fans⁸</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Install 1 kW or greater of solar electric</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
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.
Attic Venting

≥1 cfm/ft² for credit

Source: www.solatube.com
### Example

Light Reflectance Value (LRV) for exemption ≥ 64%

<table>
<thead>
<tr>
<th>Color Collection</th>
<th>SW Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color Family</td>
<td>Blues</td>
</tr>
<tr>
<td>Color Strip</td>
<td>113</td>
</tr>
<tr>
<td>RGB Value</td>
<td>R-212</td>
</tr>
<tr>
<td>Hexadecimal Value</td>
<td>#D4E7EA</td>
</tr>
</tbody>
</table>

**LRV** 78 — OK, LRV 78

<table>
<thead>
<tr>
<th>Color Collection</th>
<th>SW Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color Family</td>
<td>Blues</td>
</tr>
<tr>
<td>Color Strip</td>
<td>113</td>
</tr>
<tr>
<td>RGB Value</td>
<td>R-184</td>
</tr>
<tr>
<td>Hexadecimal Value</td>
<td>#B8DEE9</td>
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</tbody>
</table>

**LRV** 69 — OK, LRV 69

<table>
<thead>
<tr>
<th>Color Collections</th>
<th>SW Color, Teen Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color Family</td>
<td>Blues</td>
</tr>
<tr>
<td>Color Strip</td>
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<tr>
<td>RGB Value</td>
<td>R-149</td>
</tr>
<tr>
<td>Hexadecimal Value</td>
<td>#95CEE0</td>
</tr>
</tbody>
</table>

**LRV** 57 — Not complying, LRV 57

Source: www.sherwin-williams.com
Wall Overhang Shading

Wall Projection Factor (WPF) ≥ 0.30

\[
\text{WPF} = \frac{A}{B}
\]
Points Option Example

- Single family home
  - 3000 ft\(^2\)
  - Metal-framed construction
  - Air conditioned with split-system AC

- Want
  - R-19 insulation in cathedral ceiling (instead of R-30)
  - R-13 wall cavity insulation (no continuous insulation)

- Questions
  1. How many points behind?
  2. What are the options that can be used for compliance?

Three points behind
- R-19 roof = -1 point
- R-13 wall = -1 point
- Area ≥2500 ft\(^2\) = - 1 point

Options
1 point: high reflectance walls
1 point: 90% HE lighting + ES appliances
1 point: wall shading
1 point: ductless AC
1 point: 13.9 SEER
2 points: 14.8 SEER
1 point: ES ceiling fans
1 point: ≥1 kW solar electric
Residential Opaque Envelope Summary

• Wall and roof, four options
  1. Tropical zone option
  2. Prescriptive Table R402.1.2
  3. Total UA
  4. Points option
Commercial Opaque Envelope Compliance Options

- Prescriptive requirements
  - Walls
    - R-value or U-factor
  - Roof
    - R-value or U-factor
    - Cool roof membrane
- Total Building Performance
- ASHRAE Standard 90.1-2013
<table>
<thead>
<tr>
<th>Type</th>
<th>Min. Insulation</th>
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<tbody>
<tr>
<td></td>
<td>Group R</td>
</tr>
<tr>
<td>Roof</td>
<td></td>
</tr>
<tr>
<td>Insulation entirely above deck</td>
<td>R-25ci</td>
</tr>
<tr>
<td>Metal building</td>
<td>R-19 + R-11 LS</td>
</tr>
<tr>
<td>Attic and other</td>
<td>R-38</td>
</tr>
<tr>
<td></td>
<td>Other</td>
</tr>
<tr>
<td></td>
<td>R-20ci</td>
</tr>
<tr>
<td></td>
<td>R-19 + R-11 LS</td>
</tr>
<tr>
<td></td>
<td>R-38</td>
</tr>
</tbody>
</table>

ci = continuous insulation
LS = layer system
## Commercial Opaque Envelope

### Roof Insulation

**Kauai version**

<table>
<thead>
<tr>
<th>Type</th>
<th>Min. Insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group R</td>
</tr>
<tr>
<td>Roof</td>
<td></td>
</tr>
<tr>
<td>Insulation entirely above deck</td>
<td>R-25ci</td>
</tr>
<tr>
<td>Metal building</td>
<td>R-19 + R-11 LS</td>
</tr>
<tr>
<td></td>
<td>R-30</td>
</tr>
<tr>
<td></td>
<td>R-19+cool roof</td>
</tr>
<tr>
<td>Attic and other</td>
<td>R-38</td>
</tr>
<tr>
<td></td>
<td>R-30</td>
</tr>
<tr>
<td></td>
<td>R-19+cool roof</td>
</tr>
</tbody>
</table>

ci = continuous insulation

Table C402.1.3
### Maui version

<table>
<thead>
<tr>
<th>Type</th>
<th>Min. Insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group R</td>
</tr>
<tr>
<td>Roof</td>
<td></td>
</tr>
<tr>
<td>Insulation entirely above deck</td>
<td>R-25ci</td>
</tr>
<tr>
<td></td>
<td>R-12.5ci</td>
</tr>
<tr>
<td>Metal building</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R-19 + R-11 LS</td>
</tr>
<tr>
<td></td>
<td>R-30</td>
</tr>
<tr>
<td></td>
<td>R-19+cool roof</td>
</tr>
<tr>
<td>Attic and other</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R-38</td>
</tr>
<tr>
<td></td>
<td>R-30</td>
</tr>
<tr>
<td></td>
<td>R-19+cool roof</td>
</tr>
</tbody>
</table>

ci = continuous insulation
**Roof Insulation Entirely Above Deck**

R-25 for group R buildings
R-20 for other buildings

Photos courtesy of PIMA (Polyisocyanurate Insulation Manufacturers Association), via www.energycodes.gov

- Polyisocyanurate  R-6/inch
- Extruded polystyrene  R-5/inch
Roof Insulation
Entirely Above Deck

Tapered insulation exception
(C402.2.2)

Meet minimum R-value here
- R-25 for group R buildings
- R-20 for other buildings

Example:
R-20 polystyrene = 4 inches

Minimum can be 3 inches

4 ft typical

$t_{min}$ at drain

$t_{min} + 1$ inch
Roof Insulation
Metal Building

R-19 + R-11 LS
& thermal block
(6 inches + 3.5 inches)
Roof Insulation Below Deck
“Attic and Other”

R-38 for all buildings (12-inch thickness)

Or U-factor ≤ 0.027

Source: www.energycodes.gov
Commercial Opaque Envelope
Low-sloped Roofs

Cool roof required
1. solar reflectance ≥0.55 + thermal emittance ≥ 0.75, or
2. solar reflectance index ≥ 64

3-year aged values

Typical products
• Single-ply membrane
• Liquid applied
# Commercial Opaque Envelope Wall Insulation

**State version**

<table>
<thead>
<tr>
<th>Type</th>
<th>Min. Insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group R</td>
</tr>
<tr>
<td><strong>Walls</strong></td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>R-5.7ci</td>
</tr>
<tr>
<td>Metal building</td>
<td>R-13 + R-6.5ci</td>
</tr>
<tr>
<td>Metal framed</td>
<td>R-13+ R-5ci</td>
</tr>
<tr>
<td></td>
<td>R-13*</td>
</tr>
<tr>
<td>Wood framed and other</td>
<td>R-13+ R-5ci</td>
</tr>
<tr>
<td></td>
<td>R-20</td>
</tr>
<tr>
<td></td>
<td>R-13*</td>
</tr>
</tbody>
</table>

ci = continuous insulation

* R-13 alone with:
  * Reflectance $\geq 0.64$, or
  * Overhang PF $\geq 0.3
## Commercial Opaque Envelope
### Wall Insulation

#### Maui and Kauai version

<table>
<thead>
<tr>
<th>Type</th>
<th>Min. Insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group R</td>
</tr>
<tr>
<td></td>
<td>Other</td>
</tr>
<tr>
<td>Walls</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>R-5.7ci</td>
</tr>
<tr>
<td></td>
<td>R-0*</td>
</tr>
<tr>
<td>Metal building</td>
<td>R-13 + R-6.5ci</td>
</tr>
<tr>
<td>Metal framed</td>
<td>R-13+ R-5ci</td>
</tr>
<tr>
<td></td>
<td>R-13**</td>
</tr>
<tr>
<td>Wood framed and other</td>
<td>R-13+ R-5ci</td>
</tr>
<tr>
<td></td>
<td>R-20</td>
</tr>
<tr>
<td></td>
<td>R-13**</td>
</tr>
</tbody>
</table>

* No insulation for mass wall with:
  - Reflectance $\geq 0.64$,
  - Overhang PF $\geq 0.3$, or
  - Thickness $\geq 6$ in.

** R-13 alone with:
  - Reflectance $\geq 0.64$, or
  - Overhang PF $\geq 0.3$

ci = continuous insulation
Commercial Mass Wall Options

- **exterior**
  - **R-5.7 insulation**
  - (1 in. polyisocyanurate or 1.25 in. polystyrene)

- **interior**
  - **U-factor ≤ 0.151**
  - Interior furring
  - **R-6 in wood** or **R-13 in metal**
Commercial Mass Wall Options

Reflectance ≥ 0.64

Overhang PF ≥ 0.3

Thickness ≥ 6 inches

Kauai & Maui Amendments
Commercial Metal-building Wall Options

R-13 faced batt
R-6.5 rigid
metal panel
girt

R-13 faced batt
R-6.5 rigid
metal furring channel

R-13 faced batt

R-12 rigid

R-13 + R-6.5 continuous
R-12 continuous

Source: http://armstrongsteel.com
Commercial
Wood-framed Wall Options

R-13 + R-3.8 continuous
R-20
R-13 + Reflectance $\geq 0.64$
R-13 + Overhang
PF $\geq 0.3$
Commercial Metal-framed Wall Options

R-13+  
R-5 continuous

R-13+  
Reflectance $\geq 0.64$

R-13+  
Overhang  
PF $\geq 0.3$
Commercial Opaque Envelope Summary

- Prescriptive requirements
  - Walls
    - R-value or U-factor
  - Roof
    - R-value or U-factor
    - Cool roof membrane
- Total Building Performance
- ASHRAE Standard 90.1-2013

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
<th>Unheated slabs</th>
<th>Heated slabs</th>
<th>Nonswinging</th>
</tr>
</thead>
<tbody>
<tr>
<td>All other</td>
<td>NR</td>
<td>R-7.5 for 12&quot; below</td>
<td>R-4.75</td>
</tr>
<tr>
<td>Group R</td>
<td>NR</td>
<td>R-7.5 for 12&quot; below</td>
<td>R-4.75</td>
</tr>
</tbody>
</table>

- Insulation entirely above roof deck
  - R-20ci, R-25ci
- Metal buildings
  - R-19 + R-11 LS
- Attic and other
  - R-38
- Mass
  - R-5.7ci, R-5.7ci
- Metal building
  - R-13 + R-6.5ci
- Metal framed
  - R-13 + R-5ci
- Wood framed and other
  - R-13 + R-3.8ci or R-20
- Below-grade wall
  - NR, NR

DBEDT STATE OF HAWAI I HAWAII STATE ENERGY OFFICE
Showing Compliance

Information required on construction documents
(Also shown on checklists)

1. Insulation materials and their \( R \)-values.
2. Fenestration \( U \)-factors and solar heat gain coefficients (SHGC).
3. Area-weighted \( U \)-factor and solar heat gain coefficients (SHGC) calculations.

Excerpt from Sections R103.2 and C103.2
COUNTY OF [COUNTY’S ENERGY CODE NAME]

To the best of my knowledge, this project’s design substantially conforms to the Residential Provisions of [COUNTY’S ENERGY CODE NAME] (2015 IECC as amended).

**COMPLIANCE METHOD**
- Tropical Zone, R401.2.1
- Prescriptive, R402
  - Roof and Wall
    - Insulation R-value, Table R401.1.2
    - Construction U-factor, Table R402.1.4
    - Total UA, R402.1.5
    - Points Option: R407
- Simulated Performance Alternative, R405
- Energy Rating Index Compliance Alternative, R406

**INFORMATION IN CONSTRUCTION DOCUMENTS**

<table>
<thead>
<tr>
<th>Envelope</th>
<th>Yes</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof insulation R-value</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Roof insulation type and location</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Roof membrane solar reflectance and thermal emittance</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Wall insulation R-value</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Wall insulation type and location</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Window and skylight SHGC</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Air leakage testing requirement</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

**Air Conditioning**
- Air conditioning equipment capacity and efficiency | ☐ | ☐ |
- Programmable thermostat | ☐ | ☐ |
- Duct insulation R-value | ☐ | ☐ |
- Duct leakage testing requirement | ☐ | ☐ |

**Electrical**
- Lighting fixture locations | ☐ | ☐ |
- Lamp type | ☐ | ☐ |
- Ceiling fans | ☐ | ☐ |
- Whole-house fan | ☐ | ☐ |

**NOTES**

**SIGNATURE:**

**DATE:**

**NAME:**

**TITLE:**

**LICENSE NO.:**
Showing Compliance Residential Certification

COMPLIANCE METHOD

- Tropical Zone. R401.2.1
- Prescriptive. R402
  - Roof and Wall
    - Insulation R-value. Table R401.1.2
    - Construction U-factor. Table R402.1.4
    - Total UA. R402.1.5
    - Points Option. R407
    - Simulated Performance Alternative. R405
    - Energy Rating Index Compliance Alternative. R406

INFORMATION IN CONSTRUCTION DOCUMENTS

**Envelope**

- Roof insulation R-value
- Roof insulation type and location
- Roof membrane solar reflectance and thermal emittance
- Wall insulation R-value
- Wall insulation type and location
- Window and skylight SHGC
- Air leakage testing requirement
COUNTY OF [COUNTY'S ENERGY CODE NAME]

To the best of my knowledge, this project’s design substantially conforms to the [CODE NAME] (2015 IECC as amended) for building envelope components (Section C402).

COMPLIANCE METHOD

☐ 2015 IECC as amended, Mandatory & Prescriptive
☐ 2015 IECC as amended, Mandatory & Total Building Performance
☐ ASHRAE Standard 90.1-2013, Mandatory & Prescriptive
☐ ASHRAE Standard 90.1-2013, Mandatory & Energy Cost Budget Method

INFORMATION IN CONSTRUCTION DOCUMENTS

<table>
<thead>
<tr>
<th>Requirement</th>
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<tr>
<td>Roof insulation R-value</td>
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<tr>
<td>Roof insulation type and location</td>
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<tr>
<td>Roof membrane solar reflectance and thermal emittance</td>
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<td>Wall insulation R-value</td>
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<tr>
<td>Wall insulation type and location</td>
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<td>Window SHGC</td>
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NOTES

SIGNATURE:

DATE:

NAME:

TITLE:

LICENSE NO.:
**Showing Compliance**

**Commercial Certification**

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**COMPLIANCE METHOD**

- ☐ 2015 IECC as amended. Mandatory & Prescriptive
- ☐ 2015 IECC as amended. Mandatory & Total Building Performance
- ☐ ASHRAE Standard 90.1-2013. Mandatory & Prescriptive
- ☐ ASHRAE Standard 90.1-2013. Mandatory & Energy Cost Budget Method

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**INFORMATION IN CONSTRUCTION DOCUMENTS**

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**DBEDT**

**HAWAII STATE**

**Energy Office**

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Please fill out the evaluation forms

Thank you!
For more information

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Energy Analyst, Hawaii State Energy Office
Office (808) 587-3811 Howard.c.wiig@Hawaii.gov

2015 IECC available:
– http://iccsafe.org/publications

State energy code website
– http://energy.hawaii.gov/hawaii-energy-building-code

County websites
– Kauai: https://www.kauai.gov/PublicWorks/Building
– Maui: https://www.mauicounty.gov/1308/Building-Plan-Review-Section

Hawaii Energy code information website
– https://hawaiienenergy.com/codes