University of Hawaii at Manoa
Building Design and Performance Standards

VOL. 2/
DESIGN+
CONSTRUCTION

Group 1 Projects

To be used by Design and Construction Teams

LOISOS + UBBELOHDE
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**Notes:**
- TO BE INCLUDED
- NO COMMISSIONING
- COMMISSIONING
- UNAFFECTED
- DECISION TO BE MADE
- N/A
- INTEGRATED DESIGN
- SP1/SP2/SP3
- UHM BDPS - VOL.2/ DESIGN + CONSTRUCTION - GROUP 1 PROJECTS

---

**Total LEED Points Achieved:** 51

1. Leed Feasibility
   -b. Leed V4 Bd+C: Ss Credit 1: Site Assessment 1
   -b. Net Zero Feasibility
   -c. Preliminary Performance Analysis
     1.1 Strategic Performance
     2. Energy Use Reduction
       -4.1 HVAC Selection + Control
       -4.2 HVAC Selection + Control
     3. Water Use Reduction
       -5.1 Water Management
     4. Landscape
       -6.1 Site Erosion
   1.2 Preliminary Performance Meetings
   1.3 Strategic Performance Meetings
   1.4 Comission

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**LOIOS + UBBELOHDE**

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2/A. PRELIMINARY ANALYSIS

Architectural Design Programs (ADP) and Project Development Reports (PDR) are commissioned by the University of Hawai‘i at Manoa (UHM) to study and identify all of the parameters that need to be considered for a project in narrative form prior to the commencement of design. These parameters include all of the existing site and building conditions, all applicable code requirements, a detailed project program, key design criteria, and an overall project budget. ADPs and PDRs (typically for larger CIP projects) are intended to be the foundational basis for design and should not be interpreted as the architectural designs themselves (to be subsequently developed when the design teams are chosen.)

Thus, ADPs and PDRs include, as part of the description of the existing site conditions, both annual weather conditions at the site and a careful analysis of the existing conditions of the site.

Climate descriptions include wind and rain patterns, sun trajectory throughout the year, storm water run-off, high and low temperatures, etc. Site conditions description consist on listing and locating existing planters, trees, utilities (visible and hidden), street traffic (traffic patterns, flow, etc.), pedestrian walkways and circulation spaces, and any other items that may have an impact on the design.

This section of the Standards specifically affects the site, program and climate analysis that focus on the elements and features that impact building performance (from energy to occupant thermal and visual comfort, lighting quality, etc...) and would be the first phase in the design process once the design team is involved in the project.

A climate analysis using typical weather data from the Honolulu Airport is provided here and should be included in all ADPs and PDRs. As a summary of the weather description included in the following pages, design teams for buildings in the UHM Campus need to be aware of the following:

1. Mixed mode conditioning strategies are critical. Thermal comfort is achievable: being outdoors, sitting on the shade and having a 1m/s air movement, provides comfort during most of the year.
2. *Sky and wind conditions change frequently throughout the day*, impacting daylighting and shading designs.

3. *Building types or designs with intense internal loads perform quite differently* and require careful analysis as described in the Modeling Addendum.

Performing a thorough site analysis is critical to understanding all the opportunities and complexities of a building site and ensuring informed decisions are made. It is especially critical to perform a more exhaustive quantitative analysis in addition to an objective description of the context for retrofit projects. This is discussed in section 2/A.1 Site and Program analysis.
2/A. PRELIMINARY ANALYSIS

2/A.1. SITE AND PROGRAM ANALYSIS

Performing a thorough site and program analysis is critical to understanding all the opportunities and complexities of a building site and ensuring informed decisions are made. For retrofit projects, it is especially critical to perform a more exhaustive quantitative performance study in addition to an objective description of the context (as included in Architectural Design Programming (ADP) and Project Development Report (PDR) documents. If a requirement included in these Standards seems unreasonable based on the scope or the existing conditions, design teams should provide justification through the site and program analysis.

1. REQUIREMENTS
   A. CERTIFICATION
      a. LEED Feasibility
         All projects will include a LEED feasibility section in the preliminary analysis submission. Refer to the appropriate LEED v4 Reference Guide for detailed requirements.
         
         b. Site Assessment
         Fulfill the requirements to achieve 1 point from “LEED v4-BD+C SS Credit 1: Site assessment”.

   B. PERFORMANCE
   Not Applicable.

   C. DESIGN
      a. Preliminary Energy Modeling
         Perform a preliminary energy modeling analysis that explores how to reduce energy loads in the building and accomplish related sustainability goals.
         
         b. Net-zero Feasibility
         Projects are not currently required to pursue net zero energy performance but must demonstrate that the potential contribution of each building project is understood as part of the overall campus move to achieving net zero performance by 2035 (ACT99).
2/A.1 Site and Program Analysis (Continued)

c. Preliminary Performance Analysis
Provide discussion and narrative on how a design solution might impact the relationships between energy efficiency, optimal acoustics, thermal comfort, ventilation, daylighting and safety.

d. Water Budget Analysis
Perform a preliminary water budget analysis, exploring how to reduce potable water loads in the building and accomplish related sustainability goals.

DESCRIPTION AND IMPLEMENTATION

a. Net Zero Feasibility Study
A net zero performance study will be developed to establish the amount of renewable energy to be generated on site in order to achieve net zero performance as required by ACT 99 by 2035 and describe the reasons why the project would produce less energy than it consumes. Refer to the Add.4.E Energy Studies:: Net Zero Feasibility Section of the Modeling Addendum for an example of a simple net zero performance study.

b. Preliminary Performance Analysis
This will identify opportunities to achieve synergies across disciplines and building systems described below and allow discussion with all relevant stakeholders.

c. Water Budget Analysis
Demonstrate how the analysis informed the design of the project, including plumbing systems; sewage conveyance and/or on-site treatment systems; rainwater quantity and quality management systems; landscaping, irrigation, and site elements; roofing systems and/or building form and geometry; and other systems.

A preliminary water budget analysis will assess and estimate the project’s potential non-potable water supply sources and water demand volumes, including the following:
- Indoor water demand. Assess flow and flush fixture design case demand volumes.
- Outdoor water demand. Assess landscape irrigation design case demand volume.
2/A.1 Site and Program Analysis (Continued)

- Supply sources. Assess all potential non-potable water supply source volumes, such as on-site rainwater and graywater and HVAC equipment condensate.

2. INTEGRATED DESIGN

A. STRATEGIC PERFORMANCE MEETINGS

a. Strategic Performance Meeting #1.
Present and discuss the preliminary analysis results. Discuss LEED certification achievement and UHM BDPS Implementation processes. Indicate areas where further research is needed and critical findings to consider during the design.

B. COMMISSIONING

Document how the above analysis informed building and site design decisions in the project’s Owner Performance Requirements (OPR) and Basis of Design (BOD) documents.

3. VERIFICATION

A preliminary set of model assumptions for performance models should be discussed as part of the preliminary analysis. Refer to requirements in 2/B. 4.1 Energy Use Intensity, 2/B.3.5 Thermal Comfort and 2/B.3.1 Lighting Quantity and Quality for a description of performance modeling requirements during the design process.

4. DELIVERABLES

A. LEED DOCUMENTATION
Submit the documentation required by USGBC for the “LEED v4-BD+C SS Credit 1: Site assessment” credit for each project phase.

B. STRATEGIC PERFORMANCE MEETING #1

a. Narratives
For each potential design solution, provide a narrative on how it might impact the relationships between energy efficiency, optimal acoustics, thermal comfort, ventilation, daylighting and safety.
Provide also narratives describing the following design approaches:
- to reduce energy use
- to reduce water use
2/A.1 Site and Program Analysis (Continued)

- to achieve good lighting
- to avoid overheating interior conditions

b. Simulations (Analysis and Results)
Provide a draft of model assumptions and other relevant information to be included in Performance Models. Document how the preliminary energy modeling analysis informed design and building form decisions in the project’s Owner Performance Requirements (OPR) and Basis of Design (BOD) documents and the eventual design of the project, including building and site program; building orientation, form and geometry, envelope and façade treatments on different orientations; elimination and/or significant downsizing of building systems (e.g., HVAC, lighting, controls, Exterior materials, interior finishes, and functional program elements); etc.

C. DESIGN REVIEW
Not required.

D. CONSTRUCTION REVIEW
Not required.

E. PERFORMANCE REVIEW
Not required.

5. RESOURCES
• LEED Reference Guides (http://www.usgbc.org/leed)

6. OTHER REQUIREMENTS TO CONSIDER
• 2/B.1.1 STRATEGIC PERFORMANCE MEETINGS
• 2/B.3.1 LIGHTING QUANTITY AND QUALITY
• 2/B.3.6 THERMAL COMFORT
• 2/B.4.1 ENERGY USE REDUCTION
• 2/B.4.3 ELECTRIC LIGHTING ENERGY
• 2/B.4.7 RENEWABLES
• 2/C.1 WATER:: USE REDUCTION
2/B. BUILDING PERFORMANCE

In this section, critical performance metrics are established for UHM new buildings and retrofits. When followed, the projects will meet code, achieve energy and environmental goals and demonstrate the benefits of high performance buildings on the campus and throughout the State. Not only that, these buildings will fulfill the required energy use policy targets established by the State of Hawaii and the University, and will also deliver superior indoor environmental quality for University occupants.

In other existing energy Standards, there are two fundamental methods to predict future building energy use: the prescriptive and the performance method. The prescriptive approach specifies minimum standards for building components such as insulation, windows, thermal mass, lighting, HVAC systems, and equipment. Based on the energy use of benchmark buildings that have these minimum standards, the prescriptive approach helps to guarantee that the subject building will not exceed a threshold of energy consumption. Using this approach can be fast and relatively straightforward, but does not account for the specific contingencies of a design and it does not allow or encourage creative flexibility and integration in the design process.

The second method of predicting building energy use is the performance approach. In this method, there is no restriction on the specific performance of individual building components and systems as long as the simulation predicts annual energy use lower than the benchmark. The performance approach generates integrated, systemic benefits and thus allows the design teams more flexibility in attaining and exceeding the project goals. It also supports holistic high performing design.

This Standard encourages the performance approach by identifying goals for both energy use and indoor environmental quality while providing guidance on how to successfully follow an integrated design process to design an optimal response for Hawaii’s climate in the UHM context in projects for new construction, larger renovations and smaller projects as possible. The Standard also recognizes the time and budget constraints of smaller projects and provides an appropriate prescriptive approach as possible for these projects.
2/B. BUILDING PERFORMANCE

2/B.1. INTEGRATED DESIGN

An integrated design process includes the active and continuing participation of occupants, building owners, building managers, architects, contractors, cost consultants, mechanical and electrical engineers, structural engineers, specifications specialists, and consultants from many specialized fields. The best high performance buildings result from continual, organized collaboration among all players throughout the building’s life cycle.

This section describes the standard operation of the integrated project team. To assure the best result, all parties must adhere to the following principles:

- Consensus on the goals
- Clear and continuous communication
- Rigorous attention to detail
- Active collaboration among all team members throughout all phases of the project
2/B. BUILDING PERFORMANCE

2/B.1. INTEGRATED DESIGN

2/B.1.1. Strategic Performance Meetings

1. REQUIREMENTS
   A. CERTIFICATION
   Fulfill the requirements to achieve 1 point from “LEED v4 BD+C IP Credit 1: Integrative process”.

   B. PERFORMANCE
   Not Applicable.

   C. DESIGN
   a. Strategic Performance Meetings
   Conduct at least 3 (three) Strategic Performance Meetings that identify the project’s performance goals required by this Standard and target the best practices as an ongoing part of design decision making.

DESCRIPTION AND IMPLEMENTATION
The intent of this Standard is to achieve optimized comfort, energy performance and savings, higher levels of program functionality, sustainable design, and lower construction costs by setting design and performance goals and consolidating the design team around those goals at the beginning of the project.

Engage the entire project team in integrating performance goals early in the design phase and in on-going decision making to maximize system integration, and the associated efficiencies and benefits of sustainable buildings.

Strategic Performance Meetings should happen:
• Before the end of schematic design (Strategic Performance Meeting #1) to state and review performance goals, manage expectations, and review the owner’s project requirements (OPR) prepared by the commissioning agent (CA)
• In the late construction document phase (Strategic Performance Meeting #2) to “quality check” the documents with particular emphasis on maintenance and operational aspects,
• After the first year of occupancy (Strategic Performance Meeting #3)
2/B.1.1 Integrated Design:: Strategic Performance Meetings (Continued)

For all meetings, the participants should include all of the following (if part of the project team): UHM representatives (UHM project coordinator, facilities management representative, end users and Operations and Maintenance personnel), commissioning agent, all design consultants (architect, engineers (mechanical, electrical, plumbing and civil), acoustic and energy consultants, lighting designer and landscape architect).

For **Strategic Performance Meeting #2**, the contractor should be involved and this meeting should also involve construction management representatives (general contractor and/or major subcontractors) and occupant representatives (faculty, operation staff, etc).

Design teams must collect and turn over documentation that will assist with efficient operations of the buildings and be beneficial to the performance of future University Projects. During these Strategic Performance Meetings, design teams should:

- Review applicable UHM BDP Standards with the whole team during the first Strategic Performance Meeting.
- When setting goals, look at each Standards requirement and seek to set goals that align or exceed this Standard.
- All viable components of both achieving a net zero energy building and required by this Standard should be implemented as appropriate.
- Complete the UHM BDP Standards Checklist and explain if any requirements cannot be achieved as appropriate.
- Review and track progress made towards project goals during each Strategic Performance meeting.
- Track progress toward required LEED Silver certification.

In order to meet energy efficiency, Indoor Environmental Quality and Comfort goals, projects should explicitly identify quantitative metrics and targets at the whole building level as well as at the system level (included in these Standards) and track them during the course of design, delivery, and operation.
2/B.1.1 Integrated Design:: Strategic Performance Meetings (Continued)
2. **INTEGRATED DESIGN**

   **A. STRATEGIC PERFORMANCE MEETINGS**

   The outcome of these Strategic Performance Meetings will be a “**UHM BDP Standards Implementation Plan**” of how each metric of the standards will be implemented, the person responsible for each, and a time line of key deliverables or implementation procedures. One Implementation Plan should focus on the design phase (submitted by the designer after Strategic Performance Meeting #1) and a second one on the construction phase (submitted by the contractor after Strategic Performance Meeting #2). They include the following requirements:

   - Submit the appropriate checklist with the goals from these Standards (from Volume 1/Project Definition), to be included in the construction drawings;
   - Submit meeting agendas, attendee list with identifying roles for each workshop;
   - Submit meeting minutes that outline performance goals, implementation procedures, topics that need further investigation or research and each team member responsible for each goal.

   Coordinate all documentation to follow consistent naming convention.

   **B. COMMISSIONING**

   Commissioning agent should attend all Strategic Performance Meetings.

   **a. Before Strategic Performance Meeting #1 (Pre-Design Phase)**

   Commissioning Agent should submit Owner’s Project Requirements (OPR).

   **b. After Strategic Performance Meeting #2**

   Commissioning agent to submit commissioning plan.

   **c. After Strategic Performance Meeting #3**

   Commissioning agent to submit on-going commissioning plan and update Operation and Maintenance Manual.

3. **VERIFICATION**

   Not Required.
4. **DELIBERABLES**
   
   **A. LEED DOCUMENTATION**
   Submit the documentation required by USGBC for the “LEED NC-v4 IP Credit 1: Integrative process” credit for each project phase.

   **B. BEFORE STRATEGIC PERFORMANCE MEETING #1**
   
   a. **Simulation Results and Analysis**
   Design team to submit analysis phase report and Initial performance model results for energy, daylight, electric lighting and thermal comfort with sensitivity or comfort load analysis.

   **C. AFTER STRATEGIC PERFORMANCE MEETING #1**
   
   a. **Narratives**
   Design team to produce a “UHM BDP Standards Implementation Plan- Design Phase” to describe implementation during the design phase and a Basis of Design (BOD) that reflects the needs developed in the Owner’s Project Requirements (OPR).

   **D. BEFORE STRATEGIC PERFORMANCE MEETING #2**
   
   a. **Simulation Results and Analysis**
   Design teams to submit complete design and base case models used for actual energy performance prediction.

   **E. AFTER STRATEGIC PERFORMANCE MEETING #2**
   
   a. **Narratives**
   Contractor to produce a “UHM BDP Standards Implementation Plan- Construction Phase” to describe implementation during the construction phase.

   **F. BEFORE STRATEGIC PERFORMANCE MEETING #3**
   
   a. **Performance Reports**
   UHM to complete performance assessment reports describing achievement of the targets and requirements in these Standards (Please refer to “3/D Post-Occupancy:: Performance Diagnostics and Maintenance” for further description of this requirement).
2/B.1.1 Integrated Design:: Strategic Performance Meetings (Continued)

These Performance Assessment Report will address the following:
1. Energy use
2. Water use
3. Indoor Environmental Quality (including thermal comfort and lighting conditions at a minimum)
4. Space Usage Observations
5. Maintenance plan (including a review of shading device performance, maintenance and operation)

6. RESOURCES
   • LEED Reference Guides (http://www.usgbc.org/leed)

7. OTHER REQUIREMENTS TO CONSIDER
   • 2/B.1.2 INTEGRATED DESIGN:: COMMISSIONING
   • 3/D PERFORMANCE DIAGNOSTIC AND MAINTENANCE
2/B. BUILDING PERFORMANCE

2/B.1. INTEGRATED DESIGN

2/B.1.2 Commissioning

1. REQUIREMENTS
   A. CERTIFICATION

Fulfill the requirements to achieve 6 points (4pts from Path 2 and 2 pts from Option 2) from "LEED v4 BD+C EA Credit 1: Enhanced commissioning".

B. PERFORMANCE
Not Applicable.

C. DESIGN
   a. Advanced Commissioning

Engage an independent, third-party commissioning agent (CA) to be responsible for commissioning and acceptance testing the following building systems and associate controls:
   • Ventilation, cooling, and dehumidification systems (mechanical and/or passive).
   • Building envelope systems, components, and assemblies to verify the airtightness and thermal and moisture integrity.
   • Lighting systems.
   • Fenestration control systems, including automatic controls for shading devices and dynamic glazing.
   • Irrigation.
   • Plumbing systems.
   • Domestic and process water pumping and mixing systems.
   • Service water heating systems.
   • Renewable energy systems.
   • Water measurement devices.
   • Energy Measurement devices.

DESCRIPTION AND IMPLEMENTATION
The intent of this requirement is to verify that fundamental building elements and systems are designed, installed, and calibrated to operate as intended, and provide
2/B.1.2 Integrated Design:: Commissioning (Continued)

for the ongoing accountability and optimization of building energy performance over time. In existing buildings, the intent is also to use the energy audit process to achieve a holistic, iterative and integrated approach to retrofitting UHM buildings, improve building operations, energy, and resource efficiency.

See applicable LEED Reference Guide for specific requirements for LEED certification Compliance.

A commissioning process should be incorporated into the predesign, construction, and first year occupancy of the building project that verifies that the delivered building and its components, assemblies, and systems comply with the documented Owner's Project Requirements (OPR).

The Commissioning Agent (CA) will be responsible for the following tasks throughout the project phases:

a. During the pre-design phase
   Similar to the enhanced commissioning requirements in LEED and ASHRAE Guideline 0, the commissioning agent (CA) (or commissioning authority (Cx)) will document the Owner's Project Requirements (OPR).

b. During the design phase
   Review the design and the construction documents to verify that construction documents include commissioning requirements and document properly all relevant sensor locations, devices and control sequences.

c. Before starting construction
   Develop a Commissioning Plan. The Commissioning Agent (CA) identifies the systems to be commissioned, describes the scope of the commissioning process, lays out a commissioning schedule, and defines the testing and reporting procedures that are integral to the commissioning process. Most commissioning plans include the following important elements:
   • Installation checks. Ensure that specified equipment and accessories are installed.
   • Performance checks. Verify and document that systems are performing as intended, and that sensors and other control devices are properly calibrated.
   • Documentation. Ensure that all required documentation has been provided,
such as a statement of the design intent and operating protocols for all building systems.

- Manuals and training. Prepare operation and maintenance (O&M) manuals and provide training to the building operations staff.

d. During the construction phase

Systems must be commissioned to verify proper performance and conformance to the Owner's Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process. Throughout the construction process, the Commissioning Agent (CA) verifies that the systems are being installed as specified, identifies any problems related to that particular system or its interaction with other systems, and makes recommendations to the owner for correcting those problems. These systems include:

- Completion of the construction checklist and verification,
- Implementation of IAQ management plan with building flush out, ventilation rates and filter changes.
- Systems that, because their operation is seasonally dependent, cannot be fully commissioned in accordance with the Cx plan at time of occupancy should be commissioned at the earliest time after occupancy when operation of systems is allowed to be fully demonstrated as determined by CA.
- Verification that lighting controls have been installed per design and are functioning as intended. This includes occupancy sensors, day lighting controls, multi-level switching, and automatic time clocks.
- Verification that ventilation and air conditioning equipment has been installed per design and that outdoor air flow, supply air flow, fluid flow, and controls function as specified in the design criteria.
- Ensure that any and all energy management and control systems (EMCSs) perform the sequence of operations and provide trend logs per design. Also establish that sensors are calibrated.

e. Before building occupancy

The Commissioning Agent should review the documentation submitted by the contractor for commissioned equipment and review (or update for existing buildings) the Operations and Maintenance manual. Verify that it includes a systems manual following the requirements of ASHRAE Guideline 4-2008 and full
warranty information. It should provide operating staff the information needed to understand and optimally operate building systems and newly implemented improvements. The Commissioning Agent (CA) should also confirm both training of building operations and maintenance staff, and that the UHM building administrator has received a copy of the Operation and Maintenance (O&M) documentation.

Acceptance tests should be performed. For each acceptance test, complete test form and include a signature and license number, as appropriate, for the party who has performed the test. This should be documented in the final commissioning report that includes:

- An assessment of the systems’ operating condition when the functional tests are conducted;
- Problems discovered and the steps taken to correct them;
- Uncorrected operational problems that the owner decided to accept;
- Functional test procedures and results;
- Reports documenting all commissioning activities as they progress; and
- A description and estimated schedule of any deferred testing.

f. Post-Occupancy

The Commissioning Agent (CA) should establish an ongoing commissioning process that includes planning, point monitoring, system testing, performance verification, corrective action response, ongoing measurement, and documentation to pro-actively address operating problems in the systems being commissioned. This will be documented in an on-going commissioning plan that defines the following:

- Roles and responsibilities;
- Measurement requirements (meters, points, metering systems, data access);
- The points to be tracked, with frequency and duration for trend monitoring;
- The limits of acceptable values for tracked points and metered values;
- The review process that will be used to evaluate performance;
- An action plan for identifying and correcting operational errors and deficiencies
- Planning for repairs needed to maintain performance;
2. **INTEGRATED DESIGN**
   
   A. **STRATEGIC PERFORMANCE MEETINGS:**
      Commissioning agent should attend all Strategic Performance Meetings.
      
      a. *After Strategic Performance Meeting #1*
      The design team must document a Basis of Design (BOD). The Commissioning Agent (CA) should review it and confirm that it reflects the needs developed in the Owner’s Project Requirements (OPR).

3. **DELIVERABLES**
   
   During the pre-design phase, Commissioning Agent to submit Owners Project Requirements (OPR).

   A. **LEED DOCUMENTATION**
      Submit the documentation required by USGBC for the "**LEED v4 BD+C EA Credit 1: Enhanced commissioning**" credit for each project phase.

   B. **DESIGN REVIEW**
      
      a. **Drawings**
      Construction drawings must include commissioning requirements with general notes that commissioning is required, at what stages and where the commissioning plan can be found.

      b. **Other submissions**
      Commissioning Agent to submit Commissioning Plan.

   C. **CONSTRUCTION REVIEW**
      
      a. **Commissioning**
      Commissioning Agent to submit the final Commissioning Report.

   D. **PERFORMANCE REVIEW**
      
      a. **Commissioning**
      Commissioning Agent to submit On-going Commissioning Plan and update Operation and Maintenance Manual.
2/B.1.2 Integrated Design:: Commissioning (Continued)

4. **RESOURCES**
   - LEED Reference Guides (http://www.usgbc.org/leed)

5. **OTHER REQUIREMENTS TO CONSIDER**
   - 2/B.1.1 STRATEGIC PERFORMANCE MEETINGS
   - 2/B.2. ENVELOPE
   - 2/B.3. IEQ
   - 2/B.4. ENERGY
   - 2/C. WATER
2/B. BUILDING PERFORMANCE

2/B.2. ENVELOPE

In order to achieve optimum conditions on an ongoing basis, green building envelopes are dynamic and adapt to changing conditions. Therefore, the overall building envelope must function simultaneously as a defensive barrier to mitigate unwanted interactions between the interior and exterior, while at the same time optimizing benefits and providing strong visual and physical connections (through balconies, windows and external doors) between the inside and out. This includes an aesthetically appropriate control of thermal gains and losses, glare, air movement, moisture, views, day lighting and sound while striving to maximize energy conservation, energy efficiency, renewable energy and other sustainable design strategies.

To achieve a comfortable and energy-efficient building in Hawaii, controlling the amount of sunlight and heat from the sun that enters the building is critical. Using site features like foliage for shading with planting on East and West elevations can prevent low sun angle exposure and provide the best shading opportunity. Landscaping also has value as a psychological benefit, as mentioned in the UHM Landscape Master Plan. Even tall narrow plantings, when viewed from inside, especially on higher floors, can produce a benefit to users, connecting them with nature and potentially reducing reflected glare and direct gains. Where site vegetation is not available, the use of overhangs to shade walls and openings and incorporating covered porches would have a similar effect. These strategies, in addition to light colored walls will help optimize thermal performance.

Other climate and location appropriate strategies include:

- For new buildings, building form and orientation should be optimized to conduct heat gain, daylight and ventilation.
- Opportunities to upgrade window systems from single glazing, should be captured in all appropriate major and minor renovations and deferred maintenance projects.
- To size openings, select glazing, and utilize shading devices (interior and exterior) to optimize daylighting and glare control while minimizing unwanted heat loss and heat gain;
- Integrate glazing with lighting, HVAC, control systems and strategic passive/hybrid design strategies to optimize occupant comfort and building performance.
2/B.2. Envelope: (Continued)

- Optimize insulation to reduce cooling energy consumption by minimizing heat gains through the building envelope;
- Moderate interior temperature extremes by using thermal mass where appropriate, using best air/vapor barrier practices and avoiding thermal bridging.

Providing users with greater control over local environments is a central strategy in most green buildings. Operability, digital control systems, and occupant education lead to elevated awareness and interactions that improve building performance and occupant satisfaction.

Passive Design Strategies reduce or eliminate the need for mechanical devices to deliver comfort to a building’s occupants. Passive design strategies incorporate natural resources of the site such as sun, water, wind and landscaping into building design and its positive functions.
2/B. BUILDING PERFORMANCE

2/B.2. ENVELOPE

2/B.2.1. Windows and Glazed Apertures

1. RECOMMENDATIONS

These Standards encourage a holistic, iterative, performance based design approach, daylight, comfort (thermal and visual) and energy performance should be proven with building simulations according to the goals stated in these Standards. This design recommendation is not mandatory IF all other performance requirements in these Standards are met.

As indicated in the performance requirements for lighting quantity and quality, thermal comfort and energy use reduction, if detailed performance modeling is not within the scope of the project, design teams are required to use the following:

a. IECC 2015 Window Specifications

Window specifications should meet the IECC 2015 Requirements for Climate Zone 1 with Hawaii Amendments (Table C402.4 Building Envelope Fenestration Maximum U-factor and SHGC Requirements).

b. Window To Wall Area

All buildings should have a window to wall area between 40 and 60%.

c. Window Operability

For all permanently occupied spaces, Ninety percent (90%) of new buildings, and seventy five percent (75%) of major renovations, (classrooms and offices at a minimum) should have operable windows that are reasonably accessible to the occupants, (i.e., precludes use of ladders to adjust the window opening). These operations must be coordinated with the HVAC system operation.

DESCRIPTION AND IMPLEMENTATION

The intent of this recommendations is to design windows that most efficiently mediate the relationship between interior and exterior, while providing optimal visual and thermal comfort and energy efficiency.
2/B.2.1. Envelope: Windows (Continued)

The design, specification, and location of glazing and windows are very important aspects of energy efficient, comfortable buildings. In particular, the following issues should be considered:

a. **Area of glazing:** The area of glazing on a façade should balance aesthetics, daylight quality and heat gains through the envelope.

b. **Location:** Where possible, windows and glazing should be designed on east and west facades to avoid unwanted heat gains. Windows should also be placed where they will provide a good view and higher up in walls to support good daylight lighting.

c. **Opening sections:** Windows with opening sections at both high and low level benefit from being able to use the stack effect to create air movement and could be used to vent hot air out of the top of rooms and draw in cooler air in at low levels. In buildings where cross ventilation is being used as a cooling strategy, air movement should be directed around people and the ‘breeze path’ between windows on opposite walls be made a direct as possible to ensure that air movement is effective.

d. **Controls:** Window opening controls should be designed to give occupants control over their local environment. This can be done by having regularly spaced windows and providing at least one opening section per 5 m (16ft) of façade and coordinating inlet and outlet aperture configurations.

e. **Glass:** The following characteristics of glass should be taken into consideration:

   • Visible light transmittance: The percentage of visible light that will pass through glass. Glass with a relatively high VT (such as 0.7) has a clear appearance and is ideal for daylighting, reducing the requirement for artificial lighting. However, clear skies and direct beam conditions in Hawaii may also cause glare issues that need to be prevented and addressed by the design team. In such cases, it is better to use view windows with well-shaded glazing. Direct beam radiation should be diffused before being delivered to the interior for more even illuminance and effectively managed heat gain.

   • Solar heat gain coefficient: The fraction of incident radiation that enters a building as heat gain. A value of 1.0 indicates that 100% of the solar gain enters the
building. A value of 0.0 indicates that no solar gain is entering the space.

- **U-values:** A measure of the rate of conductive heat transfer through the glazing as a result of the temperature change between inside and outside surfaces.
- **Decreasing U-values**, for instance by using non-metallic frames or double-glazing, reduces heat losses and gains. No single glazing or louvers are accepted if fulfillment of both comfort and lighting quality requirements cannot be proven.
- **Spectral selectivity.** The ability of glazing material to admit visible light while rejecting unwanted infrared heat and ultraviolet wavelengths. Specifying glass with a relatively high VT and a low SHGC results in a spectrally selective glazing with good properties for daylighting the space in a non-residential building.

### f. Air leakage Requirements

Comply with the IECC 2015 air leakage requirements. Exceptions are: Field-fabricated fenestration assemblies and Fenestration in buildings that comply with the air barrier testing alternative.

### 2. INTEGRATED DESIGN

#### A. STRATEGIC PERFORMANCE MEETINGS

Envelope design and specifications will be a critical topic to discuss during both Strategic Performance Meeting #1 and #2.

#### B. COMMISSIONING

Systems must be commissioned to verify proper performance and conformance to the Owner's Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.

Commissioning agent (CA) to be responsible for commissioning and acceptance testing of building envelope systems, components, and assemblies to verify the airtightness and thermal and moisture integrity and fenestration control systems, including automatic controls for dynamic glazing.

### 3. VERIFICATION

The performance of these components should be evaluated in the computational models for thermal comfort, daylight and energy if specifications different from the IECC 2015 requirements are included in the project.
4. **DELIVERABLES**
   
   **A. LEED DOCUMENTATION**
   Not required.

   **B. DESIGN REVIEW**
   
   **a. Drawings**
   - Design teams must indicate in all building elevations the window to wall ratio.
   - Design teams must indicate in all building elevations the percentage of opening area for each total window area.
   - Construction drawings must include window specifications that match the energy and comfort model assumptions for the project.

   **C. CONSTRUCTION REVIEW**
   
   **a. Commissioning**
   Include the fenestration as part of the final commissioning report.

   **D. PERFORMANCE REVIEW**
   Not required.

5. **RESOURCES**
   
   • UHM BDPS: Modeling Addendum

6. **OTHER REQUIREMENTS TO CONSIDER**
   
   • 2/B.1.2 COMMISSIONING
   • 2/B.3.1. LIGHTING QUANTITY AND QUALITY
   • 2/B.3.5 THERMAL COMFORT
   • 2/B.4.1. ENERGY USE REDUCTION
2/B. BUILDING PERFORMANCE

2/B.2. ENVELOPE

2/B.2.2. Shading

1. REQUIREMENTS
   
   A. CERTIFICATION
   
   Not Applicable.

   B. PERFORMANCE
   
   In order to prove required shading performance, design teams should pursue one of the two options described below. These Standards encourage a holistic, iterative, performance based design approach. Daylight, comfort (thermal and visual) and energy performance should be proven with building simulations [Option 1] according to the goals stated throughout these Standards. If detailed performance modeling is not within the scope of the project, design teams are encouraged to use a prescriptive recommendation for shading profile angles [Option 2].

   **OPTION 1:: Maximum Annual Solar Exposure**

   Evaluate shading device performance to prove a Maximum Annual Solar Exposure (ASE) of 10% for key space types (classroom and offices at a minimum) for each orientation.

   **OPTION 2:: Profile Angles**

   All buildings should have exterior shading devices in all four orientations, according to the following criteria:

   - For south facades, tilting or fixed with profile angle between 45 and 65 degrees louvers. A single overhang with the same profile angle range is also accepted as long as the daylight performance requirements are met.
   - For east and west facades, fully automated louvers outperform all other shading options. Fixed strategies with profile angle between 35 (West) or 45 (East) and 65 degrees are also accepted but are less effective near the window because of low sun angles.
   - For north facades, a fixed horizontal overhang with profile angle higher than 65 degrees.
C. DESIGN

a. Exterior Shading Devices

All exterior windows should have shading devices that block direct solar radiation during the hottest times of the day. These shading devices should be designed to avoid interference with achieving good daylight conditions as required in 2/B.3.1. Building Performance:: IEQ:: Lighting Quantity and Quality for the changing sky conditions in Hawaii.

b. Direct View To The Horizon And Low Altitude Sky

In all cases, where the view to the sky is not obstructed by vegetation, topography or surrounding buildings (except those with large white surfaces that receive direct sun) and there is a direct view to the horizon and low altitude sky some additional dynamic response is necessary. The two Preferred options are automated interior fabric roller shades or automated exterior louvers. Please refer to the description and implementation section of this standard for further required specifications for these options.

DESCRIPTION AND IMPLEMENTATION

The intent of this requirement is to optimize solar control and maximize useful daylight illuminance. The sky conditions in Hawaii pose some unique challenges to meeting these demands. The latitude and local climate conditions lead to periods of very bright skies even at the horizon mixed with rapidly changing and sometimes quite dark skies. In order to maintain visual comfort inside the building the window wall needs a response the reduces the brightness of the view to the sky, but still allows enough daylight during darker sky conditions.

In cases where the view to the sky is obstructed by vegetation, topography and surrounding buildings (except those with large white surfaces that receive direct sun), exterior shading (fixed horizontal overhang or fixed louvers) that effectively blocks direct sun on the window works alone to create a visually comfortable interior.

In all other cases where there is a direct view to the horizon and low altitude sky some dynamic response is necessary. Two Preferred options are recommended:

- Option 1:: Automated Interior fabric roller shades. This is a compliment to fixed exterior overhangs that meet the profile angle requirements for each orientation.
  
  Fabric on East and West facades where a direct view out the window is unavoidable
for people seated at desks should have an openness of 1% and a visible light transmittance > 5%. North and South facades, as well as East and West facades where desks are arranged facing perpendicular to the window should have an openness of 3% and visible light transmittance > 10%.

- Option 2:: Automated exterior louvers. Louvers should be light in color and matte in appearance. They should be capable of adjusting the profile angle for light penetration between 10 (mostly closed) and 45 degrees (1:1 ratio between louver spacing and louver depth).

Automated Interior Shades could be considered as a standard to provide energy savings from daylight dimming. Direct sun should be avoided but, when unavoidable, direct sun on pulled shade results in daylit interior without the need for electric lights, maintained by opening shades when the sun moves away. The lack of successful examples in the past, has led to pushbacks but it has now been proved that less maintenance is needed with automated shades than with tangled pull chains on manual shades. Current motor technologies are very quiet and shade movement is subtle and only noticed when watched for (about 1-2 inches of movement every 5-10 minutes) automate it as needed in multi-occupant spaces, such as classrooms to enable adjustments that meet group needs and preferences.

2. **INTEGRATED DESIGN**

   **A. STRATEGIC PERFORMANCE MEETINGS**

   - *Strategic Performance Meetings #1 and #2*: Envelope design and specifications will be a critical topic to discuss during both Strategic Performance Meeting #1 and #2.

   - *Strategic Performance Meeting #3*: Review and discuss shading device performance, maintenance and operation as part of the performance assessment report.

   **B. COMMISSIONING**

   Systems must be commissioned to verify proper performance and conformance to the Owner's Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.
2/B.2.2 Envelope:: Shading (Continued)

Commissioning agent (CA) to be responsible for commissioning and acceptance testing of building envelope systems, components, and assemblies to verify the airtightness and thermal and moisture integrity and fenestration control systems, including automatic controls for shading devices.

3. **VERIFICATION**

The performance of different exterior shading strategies should be evaluated in terms of the amount of useful daylight (percentage of the space that achieve between 30 and 300 FC with fractional credit for values below 30 FC) inside the space for each orientation. Models and output results should be coordinated with requirement “2/B.3.1. Lighting Quantity and Quality”

Please refer to the Modeling Addendum of these Standards for reference on how to optimize solar controls and evaluate shading performance.

4. **DELIVERABLES**

**A. LEED DOCUMENTATION**

Not required.

**B. DESIGN REVIEW**

*a. Drawings*

Provide the Effective Shading Coefficients for every typical window configuration on each orientation.

OR

Provide the Profile Angles for every typical window configuration on each orientation.

*b. Simulations (Analysis and Results)*

Simulate the annual path of the sun relative to the building fenestration including the exterior shading devices and report the resultant hours of direct sun penetration and the hours of interior shade deployment to block sun penetration according to the designed exterior shade profile angles. Provide a report describing analysis process and results.
C. CONSTRUCTION REVIEW

a. Operation Manual
Provide Operations & Maintenance Manuals for all automated shading devices and controls.

b. Commissioning
Include shading devices (both exterior and interior) as part of the final commissioning report.

c. Training
UHM personnel must be trained on how to operate and troubleshoot the systems.

D. PERFORMANCE REVIEW

a. Performance Reports
Complete a performance assessment report describing daylighting Conditions and shading operation Post-Occupancy (Please refer to “3/D Post-Occupancy: Performance Diagnostics and Maintenance” for further description of this requirement).

b. Commissioning
Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.

5. RESOURCES
• UHM BDPS: Modeling Addendum

6. OTHER REQUIREMENTS TO CONSIDER
• 2/B.1.2 COMMISSIONING
• 2/B.3.1. LIGHTING QUANTITY AND QUALITY
• 2/B.3.5 THERMAL COMFORT
• 2/B.4.1. ENERGY USE REDUCTION
7. **TOOLS TO CREATE DOCUMENTATION**
   
   **a. How to determine direct beam penetration and size shading devices?**
   Many digital modeling programs, such as Google Sketchup and Autodesk 3D Studio Max, allow the user the ability to control the sun's position by time, date, and latitude. Such programs do not necessarily render daylight correctly, though they are good tools for understanding the patterns of direct sun into a building. By modeling a building and looking at the extremes of the year (December 21 and June 21 in the morning, noon, and afternoon) designers can get a good sense of how direct sun will interact with the architecture. Parametric modeling through informed trial and error is an excellent method for balancing aesthetics, constructability, and shade in the early design stages.
2/B. BUILDING PERFORMANCE

2/B.2. ENVELOPE

2/B.2.3. Opaque Surfaces

1. RECOMMENDATION

These Standards encourage a holistic, iterative, performance based design approach, daylight, comfort (thermal and visual) and energy performance should be proven with building simulations according to the goals stated in these Standards. This design recommendation is not mandatory IF all other performance requirements in these Standards are met.

If detailed performance modeling is not within the scope of the project, design teams are required to use the following:

   a. IECC 2015 Thermal Envelope Requirements

   Follow all Prescriptive Building Thermal Envelope Requirements (Section C402) from IECC 2015, including specific insulation requirements, roof solar reflectance and solar emittance and air leakage of building envelope assemblies with the amendments for Hawaii.

DESCRIPTION AND IMPLEMENTATION

The intent of this requirement is to optimize the physical components of the building itself as passive mechanisms for regulating interior thermal conditions. Slow thermal heat transfer into a building involves an understanding of the mechanisms of heat transfer: heat conduction, convective heat transfer, and thermal radiation (primarily from the sun).

Reflective materials and low conductive materials should be employed whenever possible in all large and small renovations, capital renewal an deferred maintenance projects. Materials used in walls, floor and other sun-exposed parts of the building should have adequate thermal resistance or reflectance.

2. INTEGRATED DESIGN

   A. STRATEGIC PERFORMANCE MEETINGS

   Envelope design and specifications will be a critical topic to discuss during both Strategic Performance Meeting #1 and #2.
2/B.2.3 Envelope:: Opaque Surfaces (Continued)

B. COMMISSIONING
Systems must be commissioned to verify proper performance and conformance to the Owner’s Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.

Commissioning agent (CA) to be responsible for commissioning and acceptance testing of building envelope systems, components, and assemblies to verify the airtightness and thermal and moisture integrity.

3. VERIFICATION
The performance of these components should be included in the computational models for thermal comfort, daylight and energy.

4. DELIVERABLES
A. LEED DOCUMENTATION
Not required.

B. DESIGN REVIEW
a. Narratives
The design team must provide a report on the materials chosen and how the opaque surfaces contribute to occupant thermal control and building energy use. Any opaque surface identified throughout the course of the design must be included in the report.

C. CONSTRUCTION REVIEW
a. Commissioning
Include these systems as part of the final commissioning report.

D. PERFORMANCE REVIEW
Not required.

5. RESOURCES
- UHM BDPS: Modeling Addendum
- IECC 2015 (http://www.iccsafe.org/codes-tech-support/codes/2015-i-codes/iecc/)
6. **OTHER REQUIREMENTS TO CONSIDER**
   - 2/B.1.2 COMMISSIONING
   - 2/B.3.1. LIGHTING QUANTITY AND QUALITY
   - 2/B.3.5 THERMAL COMFORT
   - 2/B.4.1. ENERGY USE REDUCTION
2/B. BUILDING PERFORMANCE

2/B.3. INDOOR ENVIRONMENTAL QUALITY

In all projects, UHM requires teams to design for superior Indoor Environmental Quality by taking a holistic view of the building design and operation. Special consideration must be given to occupant comfort (thermal and visual) as well as the health implications of material selection and building operation.

The intent of the following requirements is:

- To produce environments that enhance human comfort, well-being, performance, and productivity by reducing sick-time.
- To optimize fresh air, use outside air wherever reasonable
- To provide and maintain indoor air quality, which is defined as: “Air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people do not express dissatisfaction.” (ASHRAE 62-2013).
- To monitor and avoid indoor air quality problems during renovation, demolition, and construction activities.
- To provide occupants with operational control of windows, lighting and HVAC systems whenever possible.
- To provide occupants with optimal lighting conditions (in terms of light quantity and quality), during both daytime and nighttime.

All Group 1 projects on University of Hawaii at Manoa campus are now required to achieve LEED Silver certification and strive for LEED Gold (UHM Executive Policy EP.4.202). It is important then to mention that all Prerequisites included in LEED v4 should be fulfilled, even if not directly included in these Standards as requirements.

For this “Indoor Environmental Quality” section, such Prerequisites not specifically part of these Standards include:

- EQ Prerequisite 1: Minimum indoor air quality performance
- EQ Prerequisite 2: Environmental tobacco smoke control

Other LEED credits not included in these Standards but that could help projects get additional points to achieve Silver or Gold Certification are:
2/B. BUILDING PERFORMANCE

2/B.3 INDOOR ENVIRONMENTAL QUALITY

2/B.3.1 Lighting Quantity and Quality

1. REQUIREMENTS

A. CERTIFICATION

Fulfill the requirements to achieve 1 point from “LEED v4 BD+C EQ Credit 6: Interior lighting” OPTION 2: LIGHTING QUALITY.

The following Performance requirements set the designs on the path to achieve 2 points from “LEED v4 BD+C EQ Credit 7: Daylight” credit. This credit is however harder to achieve as it only accounts for regularly occupied spaces in the whole building.

B. PERFORMANCE

These Standards encourage a holistic, iterative, performance based design approach. In order to prove required lighting performance, design teams should pursue one of the following two options:

- Run building simulations to prove fulfillment of requirements for quantity and quality of daylight and electric light, including indirect lighting and glare control. [Option 1]
- If detailed performance modeling is not within the scope of the project, follow a set of design requirements including envelope design, window specifications, sun and glare control, program and space planning, fixture distribution and mounting and surface brightness [Option 2].

OPTION 1

1.a Quantity Of Daylight In The Space [OPTION 1]

Ensure appropriate illumination levels on all worksurfaces (vertical and horizontal) and circulation area floors at all times including nighttime.

For classroom, office and laboratory spaces, demonstrate through computer modeling that all key spaces for each orientation achieve both:

- Multiple Point Verification: illuminance levels are between 30Fc and 300 Fc for 9 a.m. and 3 p.m. on March 21st, AND
- Daylight Autonomy (DA) verification: Daylight Autonomy is at 55%.

Coordinate shading requirements with daylighting needs. Please refer to “2/B.2.2

[2/B.3.1 Lighting Quantity and Quality]
OPTION 1 (Continued)

Building Performance:: Envelope:: Shading" for examples of how to evaluate solar control options according to daylighting performance.

1.b Quality of Light In The Space  [OPTION 1]
Create luminous environment that is visually comfortable, avoiding excessive contrast ratios and non-uniform indirect lighting. Define the appropriate visual field for at least each typical permanently occupied space and locate potential glare sources in the visual field of each typical permanently occupied space. Consider overall scene brightness and vertical eye illuminance against the brightness of potential glare sources, and target the following contrast ratios (luminance):
- 1:3 for immediate visual task surroundings,
- 1:10 when looking up and around from that task,
- 1:20 if the room is daylit (expectations of comfort expand when the light source is natural),
- 1:40 if the bright zone/object is far in the periphery.

1.c Quantity Of Light For Electric Lighting  [OPTION 1]
Ensure that electric lighting is designed in coordination with the daylighting system to reduce energy consumption while maintaining desired lighting performance. Average maintained lighting at work surfaces should be 30fc, with minimum of 25fc

1.d Indirect Lighting  [OPTION 1]
For regularly occupied work areas (offices, classrooms and labs) use a combination of direct and indirect sources so that:
- Ceilings have an average illumination between 20% and 150% of average worksurface illumination.
- Large uninterrupted opaque vertical surfaces (portions free of windows and doors) and larger than 100 sf) should have average illumination between 30% and 150% of average worksurface illumination.

1.e. Electric Lighting Glare Control  [OPTION 1]
Maintain a maximum of 10:1 illumination level between any two points within 10 feet of each other on any uninterrupted ceiling and vertical surface larger than 100sf.
2/B.3.1 IEQ:: Lighting Quantity and Quality (Continued)

**OPTION 2**

2.a. Window Design and Specifications [OPTION 2]

2.b Sun and Glare Control [OPTION 2]
In all cases, where the view to the sky is not obstructed by vegetation, topography, surrounding buildings (except those with large white surfaces that receive direct sun) or exterior shading and there is a direct view to the horizon and low altitude sky, automated interior fabric roller shades should be installed.

2.c. Optimize Daylight Penetration [OPTION 2]
Optimize the depth of daylight penetration into the space by keeping the path between the high areas of glazing and the room as unobstructed as possible.

- Keep the ceiling height higher than the head height of the glazing and keep it that height as much as possible, especially within 15 feet of the exterior wall.
- Coordinate mechanical system components (such as ducts or radiant panels) and structural retrofits so they do not block daylight from exterior glazing.

2.d. Surface brightness [OPTION 2]
Specify surface finishes that distribute available light throughout the space and minimize contrast ratios near the exterior wall glazing and to make indirect lighting efficient.

- Ceilings should be matte white with a reflectance greater than 80%.
- Walls and partitions should be matte finish with a reflectance equal to or greater than 60%.
- Floors should be no less than 40% reflectance in the daylighted zone (within 15’ of the exterior glazing).
- Ductwork and structural elements should be considered part of the ceiling finish.

2.e. Maximum Candlepower [OPTION 2]
For fixtures with light emitting surface visible to occupants, limit luminaire candlepower to 300 cd at a vertical angle of 55 degrees for the following:

- When fixtures are orthogonal to desks: at 0 and 90 degree horizontal angles.
- When fixtures are not orthogonal to desks: at 0, 22.5, 45, 67.5, and 90 degree horizontal angles.
OPTION 2 (Continued)

2.f. Fixture Mounting [OPTION 2]
Top of ceiling fixtures with indirect component to be minimum of 18” away from ceiling surface or other exposed objects (ducts, sprinkler pipes, etc).
Use wall wash fixtures at distance from wall of 1/4 to 1/3 of wall height from the wall they are to illuminate. Wall wash fixtures to have max. candela directed between 10 and 30 degrees from vertical, and max candela value at least 1.5 times any value within 0 to 45 degrees from horizontal.

2.g. Fixture Distribution [OPTION 2]
For all ceiling fixtures with indirect component and located within 3 feet of ceiling use uplight with non-lambertian distribution and preferably a performance batwing distribution (max. candela between 10 and 35 degrees above horizontal, and max candela at least two times value of vertical candela value).
Continuous linear or regularly spaced discrete wall wash fixtures may be used. If regularly spaced discrete fixtures are used ensure adequate density to meet performance requirements above.

C. DESIGN
The essentials of making the most of the daylight delivered through the building envelope to the interior are the same for all building scales and especially important for partial renovation projects that cannot alter the basic building massing and envelope. In order to achieve required lighting performance, all projects are encouraged to include a set of design requirements in the scope regarding program and space planning and color rendering.

a. Overall Programmatic Organization.
The location and organization of programmatic spaces within the plan and section of the building should make best use of available daylight for visual comfort, energy savings, connection with nature and occupant delight.
b. Space Planning to Avoid Glare

Plan interior spaces to maximize visual comfort:

- Orient occupants and presentation boards relative to daylight apertures so that daylight arrives from the side of the task. Office workstations and desks should be arranged so that no one is looking at a monitor with a window or bright aperture in the field of view.

- Orient monitors and presentation screens so that veiling reflections of the windows are not visible. Often, veiling reflections not resolved with workspace orientation can be solved with window shades. However, if veiling reflections are still a potential issue, plan ahead for local solutions and provide partitions or desk-scale furnishings to block the reflections received by the monitor screen.

- Partitions used for privacy and acoustical control should also be reviewed for daylight transmission properties and reflectance so they do not block daylight more than necessary. Location and design of these partitions may help with visual comfort if veiling reflections and glare are a problem.

- In classrooms, mount the screen or presentation board on a solid wall positioned so that it does not receive direct daylight from a bright source. If the room has a window wall or a view to a window wall, specify operable shades to allow the occupants to control the reflections and view.

c. Color Rendering

When TM-30 data (preferred metric) is published, use sources that have a fidelity index (Rf) of at least 80, a skin fidelity index (Rf,skin) of at least 80, a gamut index (Rg) in the range of 90 to 120, and minimize red chroma shift (Rcs, h16) to the -15% to +10% range. Note: If TM-30 data is not published, it can be calculated from a spectral power distribution (SPD), available in an LM-79 test report and software available with purchase of the TM30 document from the IES.

When TM-30 data is not available, it is acceptable to use sources that have a minimum 80 CRI and R9 of at least 7.
2/B.3.1 IEQ:: Lighting Quantity and Quality (Continued)

DESCRIPTION AND IMPLEMENTATION
The intent of this Standard is to achieve optimal use of natural daylight in order to reduce dependence on electrical lighting sources, as well as improve occupant connection to the outdoors and achieve high quality lighting conditions with electric lighting. This Standard establishes as guiding principle that daylight be treated as the primary source of light, and that electric lighting is considered supplemental. Design teams should consider the luminous environment without separating daylighting and electric lighting. This includes defining zones for electric lights and selecting proper task and ambient lights.

Proper light quality is important. Projects should ensure that luminance ratios are appropriate for the users, activities, and tasks with daylight visual comfort. Use design strategies and features (e.g., shading, selection of lighting fixtures, installations, and controls) to avoid glare in ways that support the program, user purposes, and preferences.

Quality issues include the uniformity of light levels and control of glare and veiling reflections. Some variation in light levels is pleasant, but too much causes eyestrain and unnecessary use of shades and electric lights. A well-daylit space has relatively even brightness, low contrast ratios (where the illuminance levels in the space vary by less than a 3:1 ratio), and windows on two sides to provide more uniform light. Glare and veiling reflections obscure people’s ability to see details and cause eyestrain. (Glare is extreme brightness in the field of view; veiling reflections are caused by vertical specular surfaces, such as computer monitors, that reflect light into the eye.) A good daylighting system avoids these problems by minimizing or eliminating direct daylight on visual tasks.

The daylight delivered to the building interior is dependent on many design aspects associated with Whole-Building scale, such as site conditions, building orientation, building massing, plan and section organization, size and dimension of floor plates and floor-to-floor heights, size and location of apertures, glazing selection, shading and curtain wall design. In Group 2 projects, the building envelope cannot be changed, including the apertures the size and locations of windows or curtain wall, framing, glazing) and exterior shading conditions. This means the amount, depth and visual comfort of daylighting is best optimized through careful attention to interior design.
decisions. Fulfilling these requirements will keep the project teams for all building scales aware of daylighting performance throughout the design process.

**a. Quantity of Light and Optimize Daylight Penetration**

Use design strategies and features to ensure that the illuminance levels are appropriate for the users, activities, and tasks during both daytime and evening hours.

Light shelves can be used as part of glazing to ensure that areas deeper in buildings receive daylight, when combined with high, reflective ceilings to bring natural light deeper into perimeter spaces and control glare and excessive contrast. Light shelves should also be easy to clean and avoid bird nesting if they are to remain effective.

Delivering useful daylight as deeply as possible into a workspace is directly related to the head height of the glazing or window. The daylighting zone is typically 1.5 - 2.0 times the head height of the glazing. For example, a 10' head height will deliver daylight useful for work 15' - 20’ into the space. Any sizeable obstruction that blocks the path of daylight from the high glazing reduces the available daylight in the space.

Early coordination with mechanical and structural members of the design/build team is essential for all disciplines to understand potential impacts on daylight delivery. If a ceiling needs to be dropped to incorporate services such as ducts, sprinklers, cables, recessed light etc., keep the lower ceiling at least 15' back from the exterior wall to allow daylight distribution into the space.

**b. Quality of Light, Sun and Glare Control**

Proper light quality is important. Ensure that luminance Ratios are appropriate for the users, activities, and tasks with daylight visual comfort. Use design strategies and features to avoid glare in ways that support the program, user purposes, and preferences. Quality issues include the uniformity of light levels and control of glare and veiling reflections. Some variation in light levels is pleasant, but too much causes eyestrain and unnecessary use of shades and electric lights. A well-daylit space has relatively even brightness, low contrast ratios (where the illuminance levels in the space vary by less than a 3:1 ratio), and windows on
two sides to provide more uniform light. Glare and veiling reflections obscure people’s ability to see details and cause eyestrain. (Glare is extreme brightness in the field of view; veiling reflections are caused by vertical specular surfaces, such as computer monitors, that reflect light into the eye.) A good daylighting system avoids these problems by minimizing or eliminating direct daylight on visual tasks.

In cases where the view to the sky is obstructed by vegetation, topography and surrounding buildings (except those with large white surfaces that receive direct sun) or exterior shading that effectively blocks direct sun on the window works alone to create a visually comfortable interior.

In all other cases where there is a direct view to the horizon and low altitude sky some dynamic response is necessary. Automated interior fabric roller shades are the preferred option. This is a compliment to fixed exterior overhangs that meet the profile angle requirements for each orientation. Fabric on East and West facades where a direct view out the window is unavoidable for people seated at desks should have an openness of 1% and a visible light transmittance > 5%. North and South facades, as well as East and West facades where desks are arranged facing perpendicular to the window should have an openness of 3% and visible light transmittance > 10%.

Direct sun should be avoided but, when unavoidable, direct sun on pulled shade results in daylit interior without the need for electric lights, maintained by opening shades when the sun moves away. The lack of successful examples in the past, has led to pushbacks but it has now been proved that less maintenance is needed with automated shades than with tangled pull chains on manual shades. Current motor technologies are very quiet and shade movement is subtle and only noticed when watched for (about 1-2 inches of movement every 5-10 minutes) automate it as needed in multi-occupant spaces, such as classrooms to enable adjustments that meet group needs and preferences.

c. Space Planning to Avoid Glare.

Visual comfort is highly dependent on avoiding discomfort glare and disabling glare. Providing a visually comfortable daylighted workspace depends on proper orientation of desks, office workstations and presentation boards relative to the window wall, as well as design of partitions and local or movable shading.
When facing a window, occupants can be exposed to high window luminance. The bright sky can cause discomfort, which will increase with over exposure time as they work at their desk. This discomfort is increased if the sky is significantly brighter than the monitor or screen they are working on, due to the high contrast ratio between the screen luminance and the sky.

In open office spaces, workstation groupings are designed with many goals for the workspace and occupants and often place occupants facing all orientations without regard to the window wall and daylight source. Finding a design solution that addresses workspace orientation to the window wall is important. Keeping occupant visual comfort a high priority during space planning and furniture selection will alleviate many issues once the space is occupied.

When bright reflections from a highly luminous source are visible on the monitor screen or presentation board, the content on the screen behind the reflections cannot be seen. These veiling reflections make very difficult to work and can become aggravating. Providing options for occupants to position their monitors and use personal moveable partitions or shades to control reflections as part of the workstation design will enable occupants to increase their visual comfort as desired. Privacy and acoustical control often result in partitions that are opaque to light and tall enough to block daylight distribution back onto the space. Partition design and location can help with daylight performance rather than hinder it if trough about early enough in the space planning process. Partitions that offer acoustical performance may also advantageously transmit or reflect daylight. Opaque lower areas may be topped with diffuse materials such as polycarbonate or diffusing glass to maintain privacy and still deliver daylight to the next workstation. If veiling reflections cannot be resolved with desk orientation diffuse partitions behind the occupant may provide the control necessary for visual comfort.

d. Balance brightness of walls, ceiling, floor, and work-surfaces.

Reflected light from interior surfaces (the IRC or “Interior Reflected Component”) provides a significant contribution to the daylighting on a work surface such as a desktop, a counter or a whiteboard.

Balanced vertical illumination in the field of view reduces contrast, enhancing
visual acuity. This can be achieved in electric lighting using wall-washing with
down-lights on perimeter surfaces.

No other surface in a typical room will contribute more to the distribution of light
than the ceiling. To aid in the proper distribution of light, a white or nearly white
ceiling is recommended, with a minimum reflectance value of 0.80. A matte finish
is preferred over a semi-gloss or semi-specular finish because it eliminates the
possibility of reflecting the images of bright light sources from within the indirect
component of luminaires. Any color or tint present in the ceiling material will also
be contained in the light reflected off that surface, so care is needed in specifying
any finish other than white or near white.

Galvanized ducts and unfinished steel kept “raw” for aesthetic effects are dark
and absorb much of the available daylight, increasing contrast ratios and visual
discomfort. Galvanized finishes can also produce specular reflections and
uncomfortable contrast ratios.

Higher reflectance materials near the exterior glazing provide a transition in
contrast between the interior surfaces and the sky seen through the exterior
glazing, providing increased visual comfort. Accent walls with bright and darker
colors are best oriented perpendicular to the glazing and should be located farther
than 15’ from the exterior glazing.

Floors have more to do with contrast reduction in the visual field than with
contributing significantly to the ambient light level in a room. Floor surfaces can
be lighter near the glazing (in the daylighting zone) and transition to darker colors
farther from the exterior glazing. Higher floor reflectance values in the daylight
zone can work as a “light shelf” to reflect daylight up to the ceiling, decreasing
contrast ratios and increasing useful daylight in the space. The reflectance value
of a cream-colored tile is 0.45, while a dark brown floor has a reflectance value
of 0.1. These two color choices will create significantly different impressions of
brightness, even though the calculated illuminance levels will be almost identical.

Finally, dark bench tops and reagent shelves with miscellaneous items contribute
to an impression of overall lower brightness even though the design meets the
target luminance at the bench. Dark bench tops should therefore be avoided, if possible.

e. **Fixture Configuration**

There are two primary aspects of the ambient lighting fixture configuration:

- Beam direction: direct, indirect, or direct/indirect.
- Fixture location relative to furniture: parallel, perpendicular, or other.

While there is no single “best” fixture configuration, a direct-indirect configuration oriented parallel to the furniture is, typically, the preferred option. (A notable exception to this guidance would be laboratories that require wash-down capabilities.)

For regularly occupied work areas (offices, classrooms and labs) use a combination of direct and indirect sources. Provide illumination of ceiling by means of at least one of the following strategies:

a. pendants with indirect component.
b. wall mounted fixtures with indirect component.
c. Partition mounted fixtures with indirect component.
d. Cove mounted fixtures with indirect component.

If ceiling height or other factors preclude the use of suspended luminaires, consider using a recessed direct-indirect fixture. This fixture is recessed into the ceiling. It has a concave reflector and perforated metal drop basket in the center. Since the drop basket extends below the ceiling plane, light is directed high-up on vertical surfaces and onto the ceiling, providing a much more uniformly lit work environment than conventional recessed fixtures (Losnegard 2004).

f. **Color Temperature**

Use design strategies and features to ensure that color temperature re, color rendering, and modeling of light are appropriate for the users, activities, and tasks. Light with good color rendering allows us to see colors accurately, or similarly to how we would see them under full spectrum light (for example daylight or incandescent light). The TM-30 metric is preferred over CRI. TM-30 measures not only fidelity as CRI does, but also gamut (saturation) and does so with 99 color samples as opposed to the 8 color samples of CRI. This set of 99 colors
2/B.3.1 IEQ:: Lighting Quantity and Quality (Continued)

were statistically selected from a library of more than 100,000 spectral reflectance measurements for real objects which included paints, textiles, natural objects, skin tones, inks, and more. TM-30 includes the metric of skin fidelity based on the average fidelity of 2 of the 99 color samples with the highest correlation in fidelity to the thousand of measured skin samples. Color saturation is not considered in CRI. Experiments have shown a preference for high average fidelity, slight oversaturation of colors, and high red saturation. TM-30 also provides graphic representation of hue and saturation changes from a reference source.

2. INTEGRATED DESIGN

A. STRATEGIC PERFORMANCE MEETINGS

a. Strategic Performance Meeting #1

Before the meeting, provide a lighting narrative with the following content:

- Specify kinds of glass that are needed for view windows and daylighting windows at a given orientation.
- Describe strategies to ensure that light will be distributed uniformly, type of overhead and task lighting fixtures that will be needed.
- Provide initial performance model results for daylight and electric lighting

b. Strategic Performance Meeting #2

Before the meeting, submit a report describing multiple parametric runs (daylight and electric lighting) comparing options of systems and strategies. Provide illumination levels on both horizontal and vertical task surfaces. For space types without task surfaces (ex. hallways) show illuminance calculations on the floor. Show uniformity ratios.

c. Strategic Performance Meeting #3: Review the building performance report that includes this topic.

B. COMMISSIONING

Systems must be commissioned to verify proper performance and conformance to the Owner’s Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.

Commissioning agent (CA) to be responsible for commissioning and acceptance testing of lighting systems.
3. **VERIFICATION**

Use computer modeling tools to ensure that interior spaces have the proper quantity as well as quality of light for a given set of tasks. Please refer to the Modeling Addendum of these Standards for examples of studies that evaluate daylight and visual comfort performance in a typical classroom.

4. **DELIVERABLES**

4a. **LEED DOCUMENTATION**

Submit the documentation required by USGBC for the "**LEED v4-BD+C EQ Credit 6: Interior lighting**" credit for each project phase.

**B. DESIGN REVIEW**

4b. **Drawings**

Submit a section through the exterior wall and workspace that calls out:

- window head height
- location and sizes of ceiling mounted mechanical equipment
- location and sizes of any structural members near the ceiling within 15’ of the window wall

Submit a plan with full furniture layouts included.

- For each workstation that directly faces a window wall, identify the alternate location available for the monitor to avoid views of the window wall.
- For each workstation that has a window wall or daylight source behind the workstation, identify the mitigation that is planned for veiling reflections.
- Dimension the distance between the window wall and the first workstation.

4b. **Narratives**

Lighting approach (including daylighting and electric lighting) and implementation of these requirements.

4c. **Information in schedules and other submissions**

Include material % reflectance on the material boards/palettes as proposed and developed during early design phases. Alternatively, submit a perspective of each space showing the daylight zone including the window wall and 20’ back with material color and % reflectance called out.
Include material/surface % reflectances in the finish schedule in the CD phase. For finishes without published reflectance data, use a surface reflectance chart to determine reflectances for the annotations.

*d. Simulations (Analysis and Results)*

Provide a report describing computer-based simulations results including point by point lighting predictions for each representative space type as part of the 50% CD package, with the assumptions for electric lighting during nighttime hours. A minimum analysis grid of 4ft by 4ft, located so that no analysis points are closer than 3ft to a wall.

C. CONSTRUCTION REVIEW

*a. Performance Measurements*

Provide Measurements taken at least 3’ from any wall on a 5’grid, that confirm fulfillment of predicted calculations. Measurements should be taken with an illuminance meter with a valid calibration certificate.

Measurements to check performance of electric lighting should be taken with non-dimmed warmed up lamps after a 10-hour burn in before project closeout. If measured lighting is below 15% of recommended measurements then adjustments, additional placements, or reconfiguration of light fixtures will be required as part of errors and omissions.

*b. Commissioning*

Include the electric lighting systems as part of the final commissioning report.

D. PERFORMANCE REVIEW

*a. Performance Reports*


*b. Commissioning*

Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.
2/B.3.1 IEQ:: Lighting Quantity and Quality (Continued)

5. **RESOURCES**
   - LEED Reference Guides (http://www.usgbc.org/leed)
   - UHM BDPS: Modeling Addendum
   - IECC 2015 (http://www.iccsafe.org/codes-tech-support/codes/2015-i-codes/iecc/)
   - Daylight in Buildings: A Source Book on Daylighting Systems and Components (gaia.lbl.gov/iea21)
   - Lawrence Berkeley Lab Daylighting Information (windows.lbl.gov/daylighting/Default.htm)
   - eLAD An eLearning platform for commercial building daylighting and lighting systems (elad.lbl.gov/index.php/Body_of_Knowledge)
   - Whole Building Design Guide (www.wbdg.org/resources/daylighting.php)
   - Autodesk Ecotect Analysis (www.autodesk.com): Weather Tool climate analysis software bundled with Ecotect
   - Climate Consultant (www.energy-design-tools.aud.ucla.edu): Climate analysis freeware
   - Radiance (radsite.lbl.gov/radiance): Main portal for Radiance software including freeware and tutorials
   - DIVA (www.diva-for-rhino.com): Radiance plug-in for Rhino

6. **OTHER REQUIREMENTS TO CONSIDER**
   - 2/B.1.2 COMMISSIONING
   - 2/B.3.5 THERMAL COMFORT
   - 2/B.4.1. ENERGY USE REDUCTION
   - 2/B.4.3 ELECTRIC LIGHTING ENERGY
7. **TOOLS TO CREATE DOCUMENTATION**

A daylighting simulation tool that can perform accurate daylight illuminance calculations for a grid of points under standard CIE skies for the times specified should be used. Similar simulations including electric lighting assumptions should also be performed with the same or a different software.

**a. How to determine where and when there will be direct sun on a site?**

Figuring out a site’s access to sun helps to not only understand daylight potential, but also potential solar heat gain, and PV energy generation potential. The most useful and accurate tool is a fisheye camera coupled with a sunpath overlay. The view through a full fisheye lens is a half-hemisphere, so by pointing it straight up at the sky’s zenith, the 360-degrees of the horizon is located around the outer circumference of the image. Since a fisheye view is dependent on a particular spot, it is a good idea to take photos at the extents of a site, such as the four corners and see how solar access changes. When setting up the camera on site, a level should be used to ensure the camera is pointing straight up, a compass to note a landmark from which to get a bearing for north-south alignment, and the person operating it should duck down below the lens when taking the picture. The software SunPath allows to overlay a sunpath diagram over this photo. Designers should check the image by comparing the position of the sun on the solar path to the time the photo was taken. There may not be an exact time correlation because of the differences between local time and solar time, but the sunpath should be accurate to within 1/2 hour.

Other tools to do a similar analysis include: the Solmetric Suneye, that combines the fisheye lens and the sunpath overlay in one device, and the iPhone Sun Seeker and SunTraker, apps that use the iPhone camera to define where the sun will appear in relation to the horizon.

**b. How to determine daylight availability?**

There are a few climate analysis tools that can quickly tell you the annual sky conditions for a site using Typical Meteorological Year (TMY) data. Autodesk Ecotect Weather Tool and Climate Consultant are two of the best. Since TMY data gives the sky conditions for all 8,760 hours of the year, it is important to graphically visualize this data in a way that is useful. You should decide what works for you, but the idea is to be able to tell how much of the year the skies are
clear, partly cloudy, or overcast. Are there certain sky conditions that dominate certain seasons? It’s always useful to compare data from a place you know well to a new site so that you have a point of reference.

c. How to determine quality and quantity of daylight?
Accurately predicting the quality or quantity of daylight in a space requires some time and expertise. Each part of the daylight system, from sky conditions and neighboring buildings, to interior materials and geometry must be carefully constructed, either physically or digitally. Physical daylight models are the most accessible and immediate path for many designers. A daylight model differs from a conventional architectural model in that it is light-tight and the materials used in the model closely simulate the reflectances and textures of the proposed design. A daylight model can be tested for light quality under analogous sky conditions as the proposed building. The quantity of light can be measured using illuminance sensors.

The accuracy of a digital daylight model depends on the expertise of the modeler and the type of modeling engine being used. Most daylight software uses highly simplified algorithms to predict light behavior and accuracy suffers, especially when complex geometry or lighting situations are considered. Radiance is a research-grade simulation engine that is extremely accurate when used correctly. While it is processor intensive and requires extensive expertise, it is unparalleled in predicting the quality and quantity of light in a space.
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2/B. BUILDING PERFORMANCE

2/B.3. INDOOR ENVIRONMENTAL QUALITY

2/B.3.2.a Indoor Air Quality:: During Construction

1. **REQUIREMENTS**
   
   **A. CERTIFICATION**
   
   Fulfill the requirements to achieve 1 point from “LEED v4-BD+C EQc3: Construction indoor air quality management plan”.

   **B. PERFORMANCE**
   
   Not Applicable.

   **C. DESIGN**
   
   Not Applicable.

   DESCRIPTION AND IMPLEMENTATION
   
   See applicable LEED Reference Guide.

2. **INTEGRATED DESIGN**

   **A. STRATEGIC PERFORMANCE MEETINGS**

   *Strategic Performance Meeting #2*: Review fulfillment of this credit's requirements in the final design and coordinate with the construction team.

   **B. COMMISSIONING**

   Systems must be commissioned to verify proper performance and conformance to the Owner's Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.

   Commissioning agent (CA) to be responsible for Implementation of IAQ management plan with building flush out, ventilation rates and filter changes.

3. **VERIFICATION**

   Not Required.
4. **DELIVERABLES**
   
   **A. LEED DOCUMENTATION**
   Submit the documentation required by USGBC to achieve the LEED credit mentioned above.

   **B. DESIGN REVIEW**
   Not required.

   **C. CONSTRUCTION REVIEW**
   Not required.

   **D. PERFORMANCE REVIEW**
   Not required.

5. **RESOURCES**
   

6. **OTHER REQUIREMENTS TO CONSIDER**
   
   • 2/B.3.2.B IEQ:: INDOOR AIR QUALITY:: AFTER CONSTRUCTION
2/B. BUILDING PERFORMANCE

2/B.3. INDOOR ENVIRONMENTAL QUALITY

2/B.3.2.b Indoor Air Quality:: After Construction

1. REQUIREMENTS

A. CERTIFICATION

Fulfill the requirements to achieve 2 points from “LEED v4-BD+C EQc4: Indoor air quality assessment” through OPTION 2. AIR TESTING.

Fulfill the requirements to achieve 2 points from “LEED v4-BD+C EQ Credit 1: Enhanced indoor air quality strategies” through both Option 1. Enhanced IAQ Strategies and Option 2. Additional Enhanced IAQ Strategies.

B. PERFORMANCE

Not Applicable.

C. DESIGN

Fulfill the following requirements that are specifically critical for the Hawaiian Climate:

a. Prevent Mold From Irrigation

In order to prevent mold do not install irrigation systems in locations where they may spray directly onto buildings.

DESCRIPTION AND IMPLEMENTATION

The intent of this Standard is to establish a minimum level of indoor air quality to protect student and staff health. Permanent irrigation systems that spray on buildings can cause structural damage and mold growth.

See also applicable LEED Reference Guide.

2. INTEGRATED DESIGN

A. STRATEGIC PERFORMANCE MEETINGS

Strategic Performance Meeting #2: Review fulfillment of this credit’s requirements in the final design and coordinate with the construction team.
2/B.3.2.b  IEQ:: Indoor Air Quality:: After Construction (Continued)

B. COMMISSIONING
Commissioning agent (CA) to be responsible for commissioning and acceptance testing of irrigation systems.
Systems must be commissioned to verify proper performance and conformance to the Owner’s Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.

3. VERIFICATION:
Not Required.

4. DELIVERABLES
A. LEED DOCUMENTATION
Submit the documentation required by USGBC to achieve the required LEED credits.

B. DESIGN REVIEW
a. Drawings
Construction drawings must include irrigation plans showing that sprinkler ranges do not intersect with buildings.

C. CONSTRUCTION REVIEW
a. Commissioning
Include the irrigation systems as part of the final commissioning report.

D. PERFORMANCE REVIEW
a. Commissioning
Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.

5. RESOURCES
• LEED Reference Guides (http://www.usgbc.org/leed)

6. OTHER REQUIREMENTS TO CONSIDER
• 2/B.4.2. HVAC SELECTION AND CONTROL
• 2/C 1.1 WATER:: USE REDUCTION: SITE
2/B. BUILDING PERFORMANCE

2/B.3. INDOOR ENVIRONMENTAL QUALITY

2/B.3.3. Low-Emitting Materials

1. REQUIREMENTS
   A. CERTIFICATION
   Fulfill the requirements to achieve 3 points from “LEED v4-BD+C EQc2: Low-emitting materials”.

   B. PERFORMANCE
   Not Applicable.

   C. DESIGN
   Not Applicable.

DESCRIPTION AND IMPLEMENTATION
See applicable LEED Reference Guide.

2. INTEGRATED DESIGN
   A. STRATEGIC PERFORMANCE MEETINGS
   Strategic Performance Meeting #2: Review fulfillment of this credit's requirements in the final design and coordinate with the construction team.

   B. COMMISSIONING
   Not Applicable

3. VERIFICATION:
   Not required.

4. DELIVERABLES
   A. LEED DOCUMENTATION
   Submit the documentation required by USGBC to achieve the LEED credit mentioned above.

   B. DESIGN REVIEW
   Not required.
C. CONSTRUCTION REVIEW
Not required.

D. PERFORMANCE REVIEW
Not required.

5. RESOURCES
• LEED Reference Guides (http://www.usgbc.org/leed)
2/B. BUILDING PERFORMANCE

2/B.3. INDOOR ENVIRONMENTAL QUALITY

2/B.3.4. Acoustics

1. REQUIREMENTS
   
   A. CERTIFICATION
   
   Fulfill the requirements to achieve 1 point from “LEED v4 BD+C EQc9: Acoustic performance” credit.

   B. PERFORMANCE
   
   Not Applicable.

   C. DESIGN
   
   Not Applicable.

DESCRIPTION AND IMPLEMENTATION

See applicable LEED Reference Guide.

2. INTEGRATED DESIGN

   A. STRATEGIC PERFORMANCE MEETINGS

   *Strategic Performance Meeting #2*: Review fulfillment of this credit's requirements in the final design and coordinate with the construction team.

   B. COMMISSIONING

   Not Applicable

3. VERIFICATION

   Not required.

4. DELIVERABLES

   A. LEED DOCUMENTATION

   Submit the documentation required by USGBC to achieve the LEED credit mentioned above.

   B. DESIGN REVIEW

   Not required.
C. CONSTRUCTION REVIEW
Not required.

D. PERFORMANCE REVIEW
Not required.

5. OTHER REQUIREMENTS TO CONSIDER
It is essential that acoustical design assist with successful design of natural ventilation.

6. RESOURCES
• LEED Reference Guides (http://www.usgbc.org/leed)
• Acoustical Society of America (http://asa.aip.org and http://asa.aip.org/classroom/booklet.html)
• American National Standards Institute (www.ansi.org)
2/B. BUILDING PERFORMANCE

2/B.3. INDOOR ENVIRONMENTAL QUALITY

2/B.3.5. Thermal Comfort

1. REQUIREMENTS
   A. CERTIFICATION

   Fulfill the requirements to achieve 1 point from “LEED v4 BD+C EQc5: Thermal comfort” through Option 1.

B. PERFORMANCE

   These Standards encourage a holistic, iterative, performance based design approach. In order to prove required thermal comfort performance, design teams should pursue one of the following two options:
   - Run building simulations to prove fulfillment of requirements for HVAC Autonomy. [Option 1]
   - If detailed performance modeling is not within the scope of the project, follow a set of design recommendations including envelope design and specifications and increasing thermal mass, [Option 2].

OPTION 1:: HVAC Autonomy

   Simulation results from unconditioned models must show that the overheating hours are less than 40% of the occupied hours or 10% of the total hours of the year in average for all orientations for key spaces in classroom and office buildings.

OPTION 2

2.a Envelope Design and Specifications [Option 2]

   Follow all Design Recommendations for windows and opaque surfaces in 2/B.2. Envelope.

2.b. Optimize Occupant Comfort [Option 2]

   Design teams should maximize thermal mass in the interior surfaces to replicate the model assumptions achieving the best results in the HVAC autonomy studies included in the Modeling Addendum of these Standards.
C. DESIGN

a. Criteria For Passively Conditioned Spaces


b. Mechanical Ventilation

Provide increased air motion (to achieve at least 2 or 3 ACH) by mechanical means (ceiling fans or conventional diffusers), without adding compressive mechanical cooling in all non-Lab regularly occupied spaces, classroom and offices at a minimum.

DESCRIPTION AND IMPLEMENTATION

The intent of this requirement is to provide appropriate thermal conditions by addressing environmental and seasonal considerations for dry bulb temperature and radiant temperature profile, relative humidity, and occupants’ activities and modes of dress.

Thermal comfort depends on several factors, including air temperature, relative humidity, air movement and the radiant temperature of surrounding surfaces. Thermal comfort is affected by heat conduction, convection, radiation, and evaporative heat loss. Thermal comfort is maintained when the heat generated by human metabolism, equipment and other activities within the building is allowed to dissipate, thus maintaining thermal equilibrium with the surroundings. Any heat gain beyond this generates a sensation of discomfort.

Hawaii's tropical and dynamic climate presents challenges: high humidity, salt laden air, intense sunlight, and variable winds must be addressed to achieve optimum comfort levels.

At UHM, the number one student complaint about their classroom is that the classrooms are too cold. Many staff cope with similar conditions in their offices by adding space heaters, covering up vents, complaining, conducting ‘thermostat wars’ with their co-workers, or simply leaving the office. Occupants can be driven to distraction trying
to adjust the comfort in their space. Improper temperature, humidity, ventilation, and indoor air quality can also have significant impacts on productivity and health.

To understand occupant comfort, these Standards include a modeling addendum with a compilation of results from simulations to study the passive ability of the building to provide comfort. These models predict the number of occupied hours that occupants will feel comfortable without mechanical conditioning (HVAC autonomy).

In this study, occupant comfort is calculated as defined by the ASHRAE 55 Adaptive Thermal Comfort Standard. Indoor operative temperatures range between 65.8°F - 86.1°F (18.78°C - 30.1°C). This assumes that occupants will wear clothing appropriate to the weather. Furthermore, air movement is assumed to be less than 40 fpm, as this is the threshold for comfort cooling due to air movement.

Observing the comfort load factors for each space, the priorities to improve thermal comfort were determined, which include increasing natural ventilation, reducing internal heat from lighting, reducing the heat gain or loss through glazing areas, and increasing the thermal mass effect. From these, studies then could identify how much comfort can be improved relying only on passive strategies and building design decisions. By parametrically modeling envelope improvements in an additive fashion, the relative effect of each measure was then quantified.

In summary, the factors associated with decreased comfort in this analysis are the solar radiation through the windows and internal loads (heat released to the space by the occupants as well as from lighting and equipment).

The analysis also indicates that ventilation and thermal mass (interior floor and wall conduction) improve building thermal performance and thus improving comfort and reducing future HVAC loads. Ventilation introducing outside air when heat is building up in the space due to high internal loads or solar radiation, can prevent overheating. Thermal mass in the floor, such as a concrete slab contributes to comfortable conditions by absorbing heat during the day and releasing it at night.
Observing the thermal comfort results, the main recommendations for classroom and offices are:

- Ceiling fans (to provide air motion) and operable windows are critical (as they allow the adaptive comfort model and bring in 1ACH of outside air beyond breathing requirements).
- For all orientations, good glazing and shading, in addition to efficient lighting with controls (both occupancy and daylight) should be part of every retrofit project, if possible.
- New buildings should be designed to include as much thermal mass and ventilation as possible (ideally, to achieve 2 or 3 ACH minimum).
- Design teams that do not have the capacity to replicate the studies presented in this section are encouraged to include the model assumptions that Achieve the highest building performance results as part of the specifications for their projects (design recommendations in these Standards).

The following criteria have been developed to set a thermal comfort standard for interior environmental conditions at UHM. Criteria are described for three different environmental classifications, based on the approach used for space conditioning.

a. **Spaces that are conditioned solely by natural ventilation**

   Interior spaces shall meet the Adaptive Comfort criteria as outlined in ASHRAE Standard 55-2013 (Section 5.3). The basic concept of adaptive comfort is that the comfort zone, or range of acceptable indoor temperatures, drifts upwards in warm weather and downwards in cooler weather, particularly in environments where occupants have a variety of adaptive opportunities at their disposal (e.g., loose dress codes, ability to partially control their own thermal environment through operable windows or other devices).

   The ASHRAE Committee that manages Standard 55 allows increases in the acceptable maximum indoor temperature for naturally ventilated spaces when there is elevated air speed. When modeling and predicting comfort conditions, this can be accounted for by increasing the upper limit of the acceptable indoor temperatures.

   Impact of outdoor humidity. Mean outdoor effective temperature, ET*, should be used as the driving function (de Dear and Brager 1998) for calculating the adaptive
comfort range. ET* is defined as the temperature at 50% relative humidity which would cause the same sensible plus latent heat exchange from a person as would the actual environment. This combines temperature and humidity into a single index, so two environments with the same ET* should provide the same thermal response even though they have different temperatures and humidities, as long as they have the same air velocities.

The optimum indoor operative temperature is given as follows:

\[
\text{optimum indoor temperature} = 18.9^\circ C + 0.255 \times \text{outdoor mean ET*}
\]

Acceptable temperature ranges around the optimum in naturally ventilated buildings were specified as ±3.5°C for 80% general acceptability and ±2.5°C for 90% general acceptability.

b. Spaces that can be conditioned by either natural ventilation or mechanical space conditioning (i.e. ‘mixed mode’)

Mixed-mode refers to a hybrid approach to space conditioning that uses a combination of natural ventilation from operable windows (either manually or automatically controlled) or other passive inlet vents, and mechanical systems that provide air distribution and some form of cooling. A well-designed mixed mode building allows spaces to be naturally ventilated during periods of the day or year when it is feasible or desirable, and uses air-conditioning for supplemental cooling and dehumidification when natural ventilation is not sufficient. The goal is to provide acceptable comfort while minimizing the significant energy use and operating costs of air conditioning (Brager 2006).

At first glance, the assessment of thermal comfort in a mixed-mode building requires the evaluation of three different operating regimes.

a. Occupied hours when spaces are conditioned solely by natural ventilation.

b. Occupied hours when spaces are conditioned by mechanical conditioning only.

c. Occupied hours that fall within an hour or two of the transition from one mode of space conditioning to the other.

For conventional, mechanically-cooled buildings, people turn to ASHRAE Std 55’s traditional comfort zone. In contrast to the field-based adaptive comfort zone just described, the traditional comfort zone is based exclusively on laboratory studies, from which was derived the widely used thermal comfort index “Predicted Mean
Vote" (PMV), which refers to a vote on a thermal sensation scale. For mixed-mode buildings, there is no agreement about how to best define the thermal comfort operating conditions in any of the three operation regimes described above. There does seem to be agreement, however, that the chosen approach requires considered discussion between the design team and the building owners (and/or managers for the occupants, if different), as well as eventual occupant education about the building operation and the occupants’ role in managing their own thermal environments. In all of these approaches, there need to be decisions about the extent to which you want to control (i.e., limit) or educate occupants about how to use the windows. These can be through automated windows, window locks, or red/green light signalling systems. In any of these approaches, whether or not people will find the PMV-based (conventional systems) or adaptive-based (natural ventilation) comfort zone acceptable has a lot to do with how the building is designed, and how it is operated throughout the year.

In UHM mixed mode buildings, the Adaptive Comfort criteria should be consistently maintained through alternative operation scenarios. Natural ventilation is used exclusively as long as conditions are maintained within the Adaptive Comfort limits as previously described. Fan assisted ventilation is activated to provide additional air movement to maintain comfort conditions when natural ventilation is not sufficient. Dehumidification is then activated if needed when outdoor conditions are beyond the acceptable humidity levels. Mechanical cooling is used only as needed to ensure the building temperature does not rise above the adaptive comfort maximum temperature. This is most appropriate for spaces that operate primarily in naturally ventilated mode during significant periods of the year, and where the occupants are well-educated about building performance, and they are willing to play an active role in managing their own thermal environment (i.e., there is sufficient adaptive opportunity so that expectations are relaxed as well).


Another important consideration, and for mixed-mode buildings in particular, is the issue of transient comfort, including comfort perception when people first enter a building. It is expected that pedestrians arriving at the building will tend to be overheated due to their higher metabolic rate in combination with warm and humid outdoor conditions. It is recommended to provide substantial air
movement in the transitional space during warm conditions. Air movement is the fastest-acting way to cool overheated people. Furthermore, air movement within rooms thins out the room surfaces’ boundary layers and desiccates surfaces so they won’t support molds. It doesn’t have to be a lot of air movement to avoid the undesirable stagnant conditions, where any drop in temperature can cause condensed moisture in room surfaces, clothes, or furnishings.

Since the corridors will not be easily amenable to natural ventilation, this increased air motion can be provided by mechanical means (ceiling fans or conventional diffusers), and again the design should emphasize increased air movement to the extent possible, before mechanical cooling (reduced temperature) is added.

Whether the decision is made to add mechanical cooling in the transitional corridors can be determined from the climate data, assumed clothing and met rate, and the SET-corrected comfort zone. If mechanical cooling is added, the least amount possible should be added. This is desirable because humidity control within a transition space with doors opening and people moving in and out will be very difficult, and the less temperature change imposed, the fewer humidity problems will arise.

Another reason not to use extensive mechanical cooling for the entry and transitional spaces is that incoming people will experience evaporative cooling on their skin when first entering the building, and overcooling the lobby down to steady-state will cause occupant discomfort. When the people continue through the transitional spaces and move into the more humid classrooms, there will be adsorptive moisture gain on the clothing which can be perceived as a pulse of heat (lasting a few minutes in lightweight clothing--45 minutes in heavier clothing like a sweater). So again in this case, ventilation to provide increased air movement is the best strategy, and the least amount of dehumidification and cooling the better for such a transitional space.

To the extent possible, it is recommended to dehumidify without significantly lowering the indoor air temperature. That can be done by using the AC’s condenser coil heat to reheat the air after it passes through the (dehumidifying) evaporator coil or a traditional dedicated dehumidifying unit. What should be avoided is to cool the structure on an intermittent basis, such as at night. In the morning...
when the doors open and humid air comes in, a cooled structure may be below dewpoint, the primary condition for mold.

In conclusion, it is required that any overnight dehumidification does not result in the building structure being cooled below the predicted dewpoint temperature for the following morning. This may allow some structural cooling, but not too much. The main thing to be avoided is condensation forming on any of the building surfaces.

d. Spaces that are conditioned by mechanical conditioning only

Interior spaces should meet the comfort criteria as outlined in Section 5 of Standard 55-2013. Spaces of this classification are representative of conventional design in which mechanical systems provide 100% of the space conditioning requirements. Thermal comfort is assessed and evaluated using normal methodologies described in Standard 55.

Note that in the design of HVAC systems, indoor comfort temperatures are traditionally calculated based on the assumption that the clothing insulation is equal to a constant value of 0.5 clo during the cooling season and a constant value of 1.0 clo during heating season. These simplified modeling assumptions need to be modified to account for the expected year-round lighter clothing levels under Hawaiian climate conditions.

Elevated air speed for mechanically conditioned (PMV-based comfort) spaces. Section 5.3.3 of ASHRAE Standard 55-2013 describes how elevated air speed can be used to increase the maximum operative temperature for acceptability under certain conditions. Limits are imposed depending on environmental and personal factors and whether the occupants have local control of air speed. Figure 3 shows an example case of equal skin heat loss contours created by the Standard Effective Temperature (SET) model, which is the basis for determining the extended range of comfort acceptability. The model, however, is not restricted to this particular case and it is acceptable to use it to determine the comfort zone for a broad range of applications.
2/B.3.5. Indoor Environmental Quality:: Thermal Comfort (Continued)

2. INTEGRATED DESIGN

A. STRATEGIC PERFORMANCE MEETINGS

a. Before Strategic Performance Meeting #1
Provide initial performance model results for thermal comfort with sensitivity or comfort load analysis.

b. Before Strategic Performance Meeting #2
Submit a report describing results from multiple parametric runs comparing options and strategies. Review fulfillment of this credit’s requirements in the final design and coordinate with the construction team.

c. Strategic Performance Meeting #3: Review the building performance report that includes this topic.

B. COMMISSIONING
Systems must be commissioned to verify proper performance and conformance to the Owner’s Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.

Figure 3: Acceptable range of operative temperature and air speeds for the comfort zone based on 1.1 met, 0.5 clo, and 0.010 humidity ratio (Figure 5.2.3.2 from ASHRAE Standard 55-2010).

Source: Thermal Comfort Standard, for consideration in Kuykendall Hall Renovation Project. April 25, 2011. Fred Bauman & Gail Brager, Center for the Built Environment, UC Berkeley
2/B.3.5. Indoor Environmental Quality:: Thermal Comfort (Continued)

Commissioning agent (CA) to be responsible for commissioning and acceptance testing of ventilation, cooling, and dehumidification systems (mechanical and/or passive).

3. **VERIFICATION**

Develop thermal comfort models during the Schematic Design phase to evaluate building performance in terms of HVAC autonomy (total hours of discomfort during both occupied times and the whole year in unconditioned spaces) for each key space type in each orientation.

Design teams that do not have the capacity to replicate the studies presented in the Modeling Addendum “HVAC Autonomy and Thermal Comfort” Section are encouraged to include as design specifications the model assumptions that achieve the highest building performance results.

*Additional Requirements for renovations*: Develop a calibrated energy model to more accurately match conditions on site. The calibrated model should be able to compute sub-hourly heat flow through building elements and HVAC systems. The model should also be calibrated for accurate modeling of envelope and HVAC systems. Actual weather data should be compared to Typical Weather data and used as appropriate to calibrate the model.

4. **DELIVERABLES**

**A. LEED DOCUMENTATION**

Submit the documentation required by USGBC for the “LEED v4 BD+C EQc5: Thermal comfort” credit for each project phase.

**B. DESIGN REVIEW**

**a. Drawings**

Construction drawings must also include a table with seasonal temperatures and humidity design criteria, and metabolic rates for each space.

- For spaces that are conditioned solely by natural ventilation, provide documentation that the requirements of ASHRAE are met, including maximum distance from a window or ventilation opening and the minimum size of ventilation openings. Construction drawings must include diagrams...
2/B.3.5. Indoor Environmental Quality: Thermal Comfort (Continued)

and calculations showing that the design meets the thermal comfort and the natural ventilation requirements. Include tables showing floor and window ratios of each space.

- For spaces that are conditioned by mechanical conditioning (including mixed mode), construction drawings must include mechanical schedules with requirements and other calculations.

b. Information in schedules and other submissions
- Provide supporting documentation with PMV/PPD calculations, and/or ASHRAE Comfort Tool results that standards have been met.
- Mechanical schedules with minimum required outside air CFM rates and MERV level by air handler type.
- Include the ASHRAE 62.1 Mechanical Ventilation Calculation Worksheet.

c. Simulations (Analysis and Results)
Submit a thermal comfort report including model assumptions and hourly results for indoor operative temperatures and mean outdoor effective temperatures (ET*), a description of the comfort conditions for each key space type and orientation. Specify number of hours when discomfort occurs, and degrees from comfort.

C. CONSTRUCTION REVIEW
a. Commissioning
Include the ventilation systems as part of the final commissioning report.

b. Operation Manual
Provide an operation and maintenance manual to UHM staff on the lighting Control systems.

c. Training
UHM personnel must be trained on how to operate and troubleshoot the systems.

D. PERFORMANCE REVIEW
a. Performance Reports
2/B.3.5. Indoor Environmental Quality:: Thermal Comfort (Continued)

b. Commissioning

Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.

5. RESOURCES

- LEED Reference Guides (http://www.usgbc.org/leed)
- UHM BDPS: Modeling Addendum
- Center for the Built Environment (CBE) Thermal Comfort Tool (http://comfort.cbe.berkeley.edu/)
- Solar Control Facades (gaia.lbl.gov/hpbf/techno_a.htm): technical information on glass and shading
- Designing with the Pilkington Sun Angle Calculator (www.sbse.org/resources/sac/PSAC_Manual.pdf)
- Thermal mass calculator, part of Material Database for Whole Building Energy Calculations (www.ornl.gov/sci/roofs+walls/AWT/Ref/sips.htm)
- WUFI (www.ornl.gov/sci/ees/etsd/btric/wufi.shtml)
- THERM (eetd.lbl.gov/eetd-software-therm.html)
- HEED (www.energy-design-tools.aud.ucla.edu/heed)
- EnergyPlus Energy Simulation Software (apps1.eere.energy.gov/buildings/energyplus/)
- COMFEN (windows.lbl.gov/software/comfen/comfen.html)
- National Institute of Building Sciences (www.wbdg.org/resources/naturalventilation.php)
- University of Hong Kong, Faculty of Architecture (www.arch.hku.hk/teaching/lectures/airvent/sect03.htm)
- NIST Natural Ventilation Resources (fire.nist.gov/bfrlpubs/bfrlall/key/key3263.html)
- Natural Ventilation in Buildings: A Design Handbook by Francis Allard and Mat Santamouris, (Best (Buildings, Energy and Solar Technology))
2/B.3.5. Indoor Environmental Quality: Thermal Comfort (Continued)

- Moving Air for Comfort by Ed Arens et al. Original Citation: ASHRAE Journal, May 51 (25), 8 – 18, 2009 1. Can be downloaded: escholarship.org/uc/item/6d94f90b

6. OTHER REQUIREMENTS TO CONSIDER

- 2/B.4.2. HVAC SELECTION AND CONTROL

7. TOOLS TO CREATE DOCUMENTATION

Use software capable of thermal comfort modeling. Use actual weather data, schedules (instead of default or placeholder inputs), site shading from trees, natural ventilation, mixed mode operation, daylight controls and other critical strategies required by this Standard need to be part of the comfort model to predict occupant comfort on an hourly basis throughout the year.

a. How to predict thermal comfort in a non-conditioned space?

It is one thing for software to report how much energy machines are using in a building, but it is quite another to report how an occupant is likely to feel. Few simulation programs accurately predict thermal comfort because it is difficult to simulate either the contribution of thermal mass to the thermodynamics of a building envelope or to the occupants therein. EnergyPlus is a simulation engine developed by the US Department of Energy that works from fundamental physical principles to simulate all of the thermodynamic exchanges that occur between the climate, a building, and an occupant. EnergyPlus is open source software, which means that it is transparently coded, but it also means that there are several third-party interfaces to the engine, including IDF Editor, Open Studio for Sketchup, Comfen, and Design Builder.

b. How to predict thermal bridging and moisture migration?

The complex interactions between heat and moisture within envelope assemblies directly influence energy consumption but are beyond the scope of what energy programs typically simulate. Analysis of thermal bridging and condensation require specialized software when trying to predict the performance of unusual interactions. THERM is software that calculates two-dimensional heat-transfer
effects in building assemblies by modeling local temperature patterns. WUFI is software that allows realistic calculation of not only heat flow but also moisture transport through assemblies. It uses actual weather data and actual material properties of vapor diffusion and liquid transport.

c. How to predict air movement?
Wind tunnels are laboratory scale facilities that generate a known air stream for use with physical models. While many wind tunnels are used to study the aerodynamics of aircraft, cars and space vehicles, the flow patterns of wind and air around and within buildings require a boundary layer wind tunnel to simulate the turbulence of the earth’s surface. Wind tunnels can generate data for the velocity, direction of flow and pressure variations in and around buildings. They also enable visualization of the flow patterns but cannot easily model thermally driven air movement such as stack ventilation.

Computational fluid dynamics (CFD) uses algorithms and calculations to simulate situations that involve fluid flows, including the flow of air. CFD analysis is increasingly used to study complex air flows and thermally driven air movement in and through building components (such as double skin facades) and urban spaces between and around buildings. While CFD offers some advantages compared to wind tunnel testing and simplified rules of thumb, there remain many problems with the ability of the computer power to handle the complex conditions of architecture. CFD validation still requires wind-tunnel data and this is likely to be the case for the foreseeable future.
2/B. BUILDING PERFORMANCE

2/B.4. ENERGY

According to the US Energy Information Administration, Hawai‘i is the most oil dependent states in the nation. Almost 90% of primary energy needs were provided by imported petroleum. In addition Hawai‘i had the highest electricity prices in the Nation. However, with the mild tropical climate, Hawai‘i had in 2010, the third lowest per capita energy use in the Nation.

University facilities can impact land, air, water, natural resources, and public health. The University of Hawaii is committed to the protection of these resources at all stages of acquisition, design, development, and operation of its campus facilities. The University of Hawai‘i at Manoa is the main research University of the ten campuses of the University of Hawai‘i system. It serves approximately 20,000 full and part-time students and consumes roughly 120 million kWh of electricity and 415,000 Utherms of synthetic natural gas annually at a total cost of at least $24.5 million. Due to the high energy rates and an air conditioning intensive climate, the resulting energy cost of $5.45 per square foot is significantly higher than most other universities in the country (compared to the $2.29 Average Annual Energy Expenditures per Square Foot of Commercial Floorspace in 2015 published by the DOE).

The Board of Regents has embraced Sustainability as a core aspect of the UH mission. The UH System, one of the largest consumers of energy in the State, has established an ambitious Sustainability policy. The goals of the University Executive Policy on Sustainability - EP 4.202 include minimizing greenhouse emissions and becoming carbon neutral by 2050. Furthermore, ACT 99, passed in June 2015, requires the University of Hawaii to establish a collective goal of net-zero energy by 2035, across all campuses.

In addition, all new projects on University of Hawaii at Manoa campus are now required to achieve LEED Silver certification and strive for LEED Gold (UHM Executive Policy EP.4.202). It is important then to mention that all Prerequisites included in LEED v4 should be fulfilled, even if not directly included in these Standards as requirements.
For this “Energy” section, such Prerequisites not specifically part of these Standards include:

- EA Prerequisite 4: Fundamental refrigerant management

Other LEED credits not included in these Standards but that could help projects get additional points to achieve Silver or Gold Certification are:

- EA Credit 6: Enhanced refrigerant management
- EA Credit 7: Green power and carbon offsets
2/B. BUILDING PERFORMANCE

2/B.4. ENERGY

2/B.4.1 Energy Use Reduction

1. REQUIREMENTS

A. CERTIFICATION

Fulfill the requirements to achieve a minimum of 13 points (30-32% improvement compared to baseline) from “LEED v4 BD+C EA Credit 2: Optimize energy performance” through Option 1: Whole-Building Energy Simulation.

B. PERFORMANCE

a. Benchmark based target achievement.

For new buildings: On a building type basis, UHM to provide Energy Use Intensity (kBtu/square foot/ year) benchmarks from existing buildings on campus. Design teams are required to provide predictive energy performance modeling results achieving a minimum of 40% reduction in total building energy use (site energy) in classroom and office buildings.

For existing: at the early project Capital Improvement Project planning stage, before the project is approved, site monitoring should be installed if not already instrumented. UHM to provide actual energy use benchmarks during at least 12 months before construction begins. Make this data available to the design team before the Strategic Performance Meetings occur. Design teams should demonstrate, via calibrated energy modeling, a minimum 40% reduction below that benchmark energy use.

The benchmark-based energy use reduction targets will be reviewed and updated if necessary every five years to ensure progress towards meeting both:

• ACT 99 (STATE OF HAWAII HB 1509): requirement for the University of Hawaii to establish a collective goal of net-zero energy by 2035, across all campuses.

• Executive Policy EP. 4-202- UH System Sustainability: energy reductions of 10% by 2020, 20% by 2025, 30% by 2030, and 40% by 2035 , and carbon neutral by 2050 compared to a 2008 baseline. It is also critical to establish a set method of gauging the GHG metric.
2/B.4.1 Energy: Energy Use Reduction (Continued)

C. DESIGN
Not Applicable.

DESCRIPTION AND IMPLEMENTATION
The intent of this requirement is to reduce environmental impacts and operational costs associated with consuming energy. In order to achieve this, design teams should consider the kama’aina (traditional, local) response to the climate, utilize the unique qualities of the Hawaiian climate including breezes and sun exposure to enhance the energy performance of the project to design for minimum energy use so as not to exceed baseline energy use intensity budget (kBtu/sqft) by building type.

As designed energy model calculations for whole building energy use should be used to accurately predict building energy use intensity. Information from architectural and engineering plans will be used to define in detail specific energy, construction and system operational profiles that include typical instructional days, non-instructional days, weekend, holiday, recess and other schedules as provided by UHM. Using data collected, the design team will develop a simulation model to monitor energy performance to sub-hourly resolution.

ASHRAE Standard 90.1 is increasingly being used to assess the energy efficiency of buildings during the design phase—especially those projects seeking a LEED rating. Typically, this involves setting goals relative to the performance of a baseline building, as defined in the standard. In practice, however, simply specifying a goal of “x% better than ASHRAE 90.1” is inadequate because it leaves several key factors open to interpretation, which in turn will affect the meaning of the percentage reduction goals.

While metrics based on ASHRAE 90.1 are useful for exploring design alternatives, many owners and designers are uncomfortable with the wide variability in modeling results. To that purpose, UHM projects should now aim to achieve an explicit energy use target that the design should meet, which also serves as a reality check for the modeled results.

While percentage reduction of total load is the primary metric that should be used, it is also useful to track percentage reduction of regulated loads, since it provides a measure of the efficiency of features that designers have significant control over.
2/B.4.1 Energy:: Energy Use Reduction (Continued)

2. INTEGRATED DESIGN
   A. STRATEGIC PERFORMANCE MEETINGS
      a. Strategic Performance Meeting #1
         Before the meeting:
         • Provide preliminary energy model results.
         • Provide a narrative describing strategies to minimize energy use.
         • Provide initial net zero feasibility study.

      b. Strategic Performance Meeting #2
         Before the meeting:
         • Submit a report describing results from multiple parametric runs comparing
           options of systems and strategies.
         • Design teams to complete design and base case models used for actual energy
           performance prediction and LEED and/or code compliance verification.
         Review fulfillment of this credit's requirements in the final design and coordinate
         with the construction team.

      c. Strategic Performance Meeting #3:
         Review the building performance report that includes this topic.

B. COMMISSIONING
   Not Applicable

3. VERIFICATION
   Code compliance or “regulatory” modeling does not require any special study of
   similar buildings but is essentially a set of analysis procedures to document
   compliance. This traditional approach has two fundamental limitations. First,
   these codes and standards only address a fraction of the energy-using systems in
   the building (they avoid regulating process loads, including “plug” loads). Second,
   the models are only as good as the assumptions about operating conditions and
   building management practices (they include assumptions about operating hours
   or equipment loads that are not representative of the conditions the building will
   eventually encounter). These limitations mean that these models are not very
   useful to inform the design team about how to improve the performance of a
   design in-process.
2/B.4.1 Energy:: Energy Use Reduction (Continued)

With the zero net energy policy goal there is an increasing expectation that building energy modeling results should also more accurately align with actual measured building energy use. There must be intent to assess performance relative to targets as-operated (measured) in addition to as-designed (modeled) and performance targets must expand from a limited set of building systems addressed by traditional codes and standards, to an all-systems accounting of energy use. Designers are required to do analysis to provide the basis for LEED compliance but also stand the test of validation by post-occupancy performance monitoring.

Modeling assumptions sensitivity analysis: Energy modeling always requires making a host of assumptions, either because some parameters are unknown, or because the modeling tool does not directly support certain building features. As a result, many building owners and designers are concerned about the validity of modeling results. The following recommendations can help to mitigate this issue:

- Understand key assumptions: Modelers should document the key assumptions and review them with designers to ensure that they are valid.
- Test the sensitivity of key assumptions: Modelers should run parametric variations on the key assumptions and document the sensitivity of the results to variations in the assumptions.

The design team should refine the thermal comfort model from “2/B.3.5 Thermal Comfort” to simulate how the building will transition between naturally ventilated and fully air-conditioned. Use a series of simulations to model strategies for how to transition between these modes of operation in order to predict facility energy use of particular strategies. Use simulation engines capable of quantifying both energy and comfort impacts of the different operational strategies. This iterative process should include simulations reflecting:

- Fully Naturally ventilated mode
- Mixed-Mode (partially natural ventilation, partially cooled, augmented by ceiling fans)

Fully Mechanically space conditioned mode (only if the two previous options do not fulfill acceptable comfort conditions)
4. **DELIVERABLES**

A. **LEED DOCUMENTATION**

Submit the documentation required by USGBC for the “LEED v4-BD+C EA Credit 2: Optimize energy performance” credit for each project phase.

B. **DESIGN REVIEW**

a. **Drawings**

Construction drawings should also include the Building Energy Performance Summary (BEPS), reflecting the designed of submitted project’s plans.

b. **Simulations (Analysis and Results)**

Submit an Energy Model Assumptions Report summarizing selected or adjusted TMY data, analysis method, description of operational strategies, and results. Include a breeze study as part of the initial project set to study the feasibility of natural ventilation.

- Provide multiple parametric runs comparing options of systems and strategies. Results will include 8760 hour matrix of energy profiles for each operational mode.
- Submit a final report summarizing the entire modeling process, including data sources and assumptions. The report will be used for ongoing procurement decisions as well as in developing a dashboard tool to present real-time feedback to classroom users to help manage daily energy consumption.
- The following documents will be included as supporting documents:
  - Sensitivity study of key assumptions
  - Detailed descriptions of iterative operating strategies modeled
  - Matrices of hourly, daily and monthly energy use by major end-uses: HVAC, interior lighting, ceiling fans and informed estimates of plug loads (computers, monitors, projector, server, etc)

C. **CONSTRUCTION REVIEW**

a. **Other**

Provide as-built energy model & electronic files.
D. PERFORMANCE REVIEW

a. Performance Reports

Complete a performance assessment report describing achievement of energy use reduction target (Please refer to “3/D Post-Occupancy:: Performance Diagnostics and Maintenance” for further description of this requirement).

5. RESOURCES

• LEED Reference Guides (http://www.usgbc.org/leed)
• UHM BDPS: Modeling Addendum

6. OTHER REQUIREMENTS TO CONSIDER

• 1/B. BENCHMARKING
• 2/B.4. ENERGY
• 3/D POST- OCCUPANCY: PERFORMANCE AND DIAGNOSTICS

7. TOOLS TO CREATE DOCUMENTATION

Use software capable of performance modeling using benchmark-based energy performance targets. Actual weather data, schedules and setpoints (instead of default or placeholder inputs), site shading from trees, natural ventilation, mixed mode operation, daylight controls and other critical strategies required by this Standard need to be part of the energy model to predict total building energy use.

Available Software include EnergyPlus, a research-grade simulation platform that accounts for sub-hourly building envelope heat flows through conduction, convection, and radiation. The model contains envelope geometry, shading devices (overhangs), and orientation, as well as assumptions about ventilation strategy, construction assemblies, and internal gains.
2/B. BUILDING PERFORMANCE

2/B.4. ENERGY

2/B.4.2 HVAC Selection and Control

1. REQUIREMENTS
   A. CERTIFICATION
   Not Applicable.

   B. PERFORMANCE
   Not Applicable.

   C. DESIGN
   In principle, HVAC systems should fulfill the thermal comfort requirements of these Standards using the conditioning strategy that requires the least amount of energy use. For all design decisions affecting mechanical systems refer to the guidelines included in the UH Manoa FMO Mechanical Standards for Consultants. In addition, designs should fulfill the following requirements that are specifically critical for the Hawaiian Climate:

   a. Mixed Mode Conditioning
   Design all buildings to be conditioned by the “mixed mode” hybrid approach that uses a combination of natural ventilation and mechanical systems that provide air distribution and some form of cooling. Natural ventilation should be used exclusively as long as conditions are maintained within the Adaptive Comfort limits, and mechanical cooling is used only as needed to ensure the building temperature does not rise above the adaptive comfort maximum temperature. Refer to the Thermal Comfort Requirements of these Standards (2/B.3.6.IEQ::Thermal Comfort) to establish the adaptive comfort limits.

   b. HVAC Specifications
   Comply with the IECC 2015 minimum efficiency requirements for all HVAC systems.

   c. Appropriate HVAC Sizing
   Avoid oversizing as a strategy to ensure adequate capacity. Appropriate sizing of AC components is critical to the design of energy-efficient AC systems.
DESCRIPTION AND IMPLEMENTATION

The intent of this requirement is to design the building ventilation and air conditioning (HVAC) system to minimize energy use while maintaining standards for indoor air quality and occupant comfort.

The approach to new buildings or refurbishment of existing facilities on the UHM campus must include and accept proven passive and hybrid design strategies. The principles of passive and hybrid design will help UHM campus buildings harness natural resources, deliver occupant comfort by reducing energy bills and green house gas emissions.

The HVAC system and controls, including the distribution system of air into the spaces, are the mechanical parts of buildings that affect thermal comfort. While not usually a part of the aesthetics of a building, they are critical to its operations and occupant satisfaction.

Hybrid and Integrated Design Strategies is the elegant combination of various passive, mechanical, programmatic and occupant solutions to meet a building’s performance demands. For instance, cooling strategies for one building could vary from room to room- day-to-day or season-to-season depending on the conditions and the occupants’ programmatic needs.

All spaces should adhere to natural ventilation guidelines such as:
- Maximize wind-induced ventilation by sitting the ridge of a building perpendicular to prevailing trade winds.
- Each room should have two separate supply and exhaust openings. Locate exhaust high above inlet to maximize stack effect. Orient windows across the room and offset from each other to maximize mixing within the room while minimizing the obstructions to airflow within the room.

The design team should:
- Group similar building functions into the same HVAC control zone so that those areas can be scheduled separately (e.g., separate around-the-clock areas from classrooms and offices).
- Modulate outside air according to occupancy, activities, and operations. Use occupancy sensors and variable air volume distribution systems to minimize unnecessary cooling.
2/B.4.2 Energy:: HVAC Selection and Control (Continued)

- Coordinate the operable window operations with the HVAC system activation.
- Use zero CFC-based refrigerants in HVAC and refrigeration equipment. Phase out CFC-based refrigerants for renovation projects.
- Comply with the IECC 2015 minimum efficiency requirements for all HVAC systems.

The minimum mechanical equipment efficiencies are those required by the National Appliance Energy Conservation Act (NAECA), the Energy Policy Act (EPACT), and the Energy Independence and Security Act (EISA).

This Standard modifies the minimum size requirements for economizers from those of Standard 90.1 and requires rooftop units with a capacity of less than 60,000 Btu/h (17 584 W) to have two stages of capacity control with the first stage relying on the economizer and the second stage adding the mechanical cooling. It also requires integrated economizers for all economized units such that the economizer and mechanical cooling can be used together. The changeover control for economizers must be either differential enthalpy or differential dry bulb. To reduce the energy waste associated with simultaneous operation of heating and cooling equipment, zone controls are required. These controls are intended to prevent reheating, recooling and mixing or simultaneous supply of air that has been previously heated with air that has been previously cooled either by mechanical systems or by an economizer.

a. HVAC Design Tools

The design tool should:
1. Calculate design cooling loads with heat balance method;
2. Calculate annual cooling load profile;
3. Do psychometric analysis for system load calculation and sizing; and
4. Provide interface to CADD programs for air duct and pipe sizing.

b. Controls

Individual HVAC zones must be capable of responding to temperatures within that zone. Humidity control devices must be provided for systems with humidification, dehumidification, or both.

Individual HVAC zones must also be equipped with setback controls that are controlled by either an automatic clock or programmable control system.
c. **Ventilation**

As a rule, buildings should have operable windows, an open lobby, and study the feasibility of avoiding an AC system unless required by the performance criteria of the end user.

Non-full height partitions allow for airflow throughout the space or floor. If full height partitions are required, provide open distribution grilles to allow ventilation room to room without mechanical ventilation.

- **Wind orientation:** Take advantage of the unique leeward location of the campus, as well as the location of the proposed building on campus.
- **Demand-controlled Ventilation:** Specify controls (both manual by user and automated) to adjust ventilation rate for spaces with varying occupancy to prevent unnecessary cooling of large quantities of outside air, and ensure that adequate ventilation is provided when needed. Ventilation systems should be designed to meet the requirements of ASHRAE Standard 62.1 Section 6.2.7. Occupancy assumptions should be shown in the design documents for spaces provided with DCV. All CO2 sensors used as part of the DCV system or any other system that dynamically controls outdoor air should meet the following: ASHRAE 189.1 Section 7.4.3.2. Please refer also to the requirements of 2/A.3.3.b **IEQ:: Indoor Air Quality:: After Construction** of these Standards.


d. **Cooling**

Air conditioning systems are intended to provide adequate cooling comfort, dehumidification, and ventilation to occupied spaces at a reasonable cost.

Like there are code compliance requirements for the building envelope, AC component ratings, and whole building energy performance, there are also code requirements for AC sizing. Both the Hawaii energy codes and ASHRAE Standard 90.1 include load calculation and sizing guidelines. However, surveys and experience have revealed that most AC systems are oversized. **Avoid oversizing as a strategy to ensure adequate capacity.** Appropriate sizing of AC components is critical to the design of energy-efficient AC systems.

Negative impacts of over sizing can be reduced by incorporating capacity controls and unloading strategies. For example:
Select multiple chillers of different sizes instead of one large chiller for redundancy and better performance;

Select a multi-compressor chiller instead of a single compressor;

Chiller; select a multi-stage compressor instead of a single-stage compressor; or select variable-speed motors instead of constant-speed motors. Try to avoid over sizing chillers, fans, pumps, and motors if there are no capacity control or unloading strategies.

e. Guidance on Component Sizing

Zone Air Flow: Zone airflow should also maintain air velocity between 10 to 50 fpm in the vicinity of occupants to prevent a draft effect, and should address ventilation and space pressurization needs.

Cooling Coil Maintenance: To improve coil heat transfer performance and reduce air-side pressure drop, select coils with a low face velocity of 250 to 300 fpm instead of 500 to 600 fpm, and low approach temperatures of 5°F to 8°F instead of 10°F to 15°F.

Chiller: At the time of writing of these Standards, there are 4 chilled water loops serving districts of 4-8 buildings. Integration and operation of these loops should be implemented as part of future revisions of these Standards.

Based on the annual load profile, selecting two or more smaller chillers to meet varying load requirements may be cost effective. Multiple chillers also provide redundancy for routine maintenance and equipment failure. For many typical facilities, sizing one chiller at one-third and another chiller at two-thirds of the peak load enables the system to meet most cooling conditions at relatively high chiller part-load efficiencies.

Cooling Tower: Once cooling capacity is determined, size the cooling tower using the ASHRAE design wet-bulb temperature conditions. Select cooling towers with multiple cells and with VSD fans.

Fans: In general, avoid over sizing fans. This Standard reduces the maximum allowable fan power by 10% versus ASHRAE Standard 90.1. If a fan has to deal with a wide range of airflows, a variable-speed drive should be installed for the fan motor. Fan efficiency should be calculated in combination w/all system components (heat exchangers, etc...).

All constant volume DX units with a capacity greater than 110,000 Btu/ h (32238 W) and all fan coils with a motor horsepower greater than 5 hp (3.7 kW) are required to have at least a two-speed fan or variable speed fan to allow for
reductions in fan power at lower loads.

- Pumps, Pipes, Ducts and Diffusers: Avoid over sizing pumps. If a pump has to deal with a wide range of water flows, a variable-speed drive should be installed for the pump motor.

As far as space and cost allow, oversized pipes will downsize pumps and save energy, as long as there are no partial flow and cavitation problems. Avoid 90° bends in piping when possible to reduce the load on the pumps.

As far as space and cost allows, over sizing air ducts will decrease air velocity and pressure drop and will allow the fan to be downsized.

Avoid over sizing diffusers because during low load conditions, airflow may be low and oversized diffusers may dump cold air.

- Efficient Air Distribution System: Design the air distribution system to minimize pressure drop and noise by increasing duct size; eliminating duct turns and specifying low-loss duct transitions and plenums. Use the lowest possible fan speed that maintains adequate airflow. Pay special attention to the longest or most restricted duct branch because the fan pressure required for adequate airflow is dictated by the duct run with the greatest pressure loss. The energy code sets requirements for duct insulation, sealing and testing. In addition, individual HVAC systems with more than 25 hp of fans face efficiency limits of 0.8 W/cfm for constant-volume systems and 1.25 W/cfm for variable-volume systems.

- Efficient Chilled Water Distribution: Utilize variable-flow chilled water distribution when a central plant is needed, and consider using a primary-only pumping system for greater energy savings.

The energy code includes several requirements related to chilled water distribution systems. Insulation is required on all chilled water pipes. Variable flow systems are required for pumping systems that include control valves that are designed to modulate flow based on load and that have pumps larger than 25 hp. This requirement covers most large chilled water-cooling systems and essentially requires the use of two-way valves rather than three-way valves that bypass unneeded chilled water around the cooling coil. Avoid hot gas, bypass systems or other passive control strategies that waste energy.

- Single-zone DX AC System: If choosing a single-zone direct-expansion (DX) system be sure to properly size the system for good dehumidification performance and consider including refrigerant sub cooling to increase the latent capacity.
2/B.4.2 Energy:: HVAC Selection and Control (Continued)

- Comply with the IECC 2015 minimum efficiency requirements for all HVAC systems (SEER value of 11.2 for both split and packaged rooftop systems smaller than 65,000 Btu/h, etc...)

- Heat Pump Water Heating and Heat Recovery: The Hawaii energy codes require heat recovery in certain buildings that have both space cooling and water heating loads. Condenser heat recovery from air conditioning or refrigeration equipment is required for any single cooling system larger than 10 tons of cooling capacity or compressor size of greater than 15 hp for buildings with service hot water heaters with more than 75,000 Btu/h or 12 kW input rating, unless the system can be shown to be not cost effective over its anticipated service life.

- Ultraviolet Light Germicidal Irradiation: Use ultraviolet (UV) light systems in air handling equipment to improve indoor air quality, control biological growth, and maintain system efficiency. ARI Standard 850-93 “Commercial and Industrial Air Filter Equipment.”

f. Dehumidification

Controlling humidity in buildings used to be a difficult undertaking that was best accomplished by overcooling the supply air to increase moisture removal, then reheating the overcooled air to the desired temperature. This was a significant waste of energy while not always ensuring good results. While gas desiccant systems have been a viable alternative, they were relatively costly and more often used for industrial applications where very low humidity levels were required. The advent in recent years of alternative dehumidification technologies has made the dehumidification process more energy efficient and affordable.

The demand for dehumidification systems for commercial buildings has been largely driven by concerns over indoor air quality (IAQ) and energy usage. Ironically, one of the major causes of IAQ problems has been a revised code requirement that have necessitated more outdoor air be introduced into buildings. As a result, outdoor air today can account for up to 80 percent of the dehumidification load in a building and can tax the ability of existing A/C systems to handle this increased latent load. Since extracting moisture from the warm moist Hawaii air is the fundamental initial energy load in AC systems, design teams should seek methods to reduce the load of conditioning outside air as a means of reducing
the overall load of HVAC systems through emerging dehumidification and other innovative technical approaches.

Any overnight dehumidification should not result in the building structure being cooled below the predicted dewpoint temperature for the following morning.

Applications for Dehumidification Systems: Classrooms: A comfortable, healthy environment is required for proper teaching and learning to take place. Concerns over illnesses caused by air-borne bacteria are another motivating factor. It is also important to note that one way of controlling mold is to ventilate a space. Stagnant air is the primary cause of mold growth. To satisfy these concerns outside air must be continuously introduced during occupied periods.

2. INTEGRATED DESIGN

A. STRATEGIC PERFORMANCE MEETINGS
   a. Strategic Performance Meeting #1
      Provide a narrative describing the conditioning approach based on the thermal comfort results from fulfilling “2/B.3.6:: IEQ:: Thermal Comfort”.

   b. Strategic Performance Meeting #2
      Before the meeting, submit a report describing results from multiple parametric runs comparing conditioning options and strategies. Compare results in terms of energy use and thermal comfort (HVAC autonomy). Review fulfillment of this credit’s requirements in the final design and coordinate with the construction team.

   c. Strategic Performance Meeting #3
      Review the building performance report that includes this topic.

B. COMMISSIONING

Systems must be commissioned to verify proper performance and conformance to the Owner’s Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.

Commissioning agent (CA) to be responsible for commissioning and acceptance testing of ventilation, cooling, and dehumidification systems (mechanical and/
2/B.4.2 Energy:: HVAC Selection and Control (Continued)

or passive). Commissioning agent (CA) should also verify that ventilation and air conditioning equipment has been installed per design and that outdoor air flow, supply air flow, fluid flow, and controls function as specified in the design criteria.

Include these systems as part of the final commissioning report and air balancing report. As part of the commissioning effort, perform systems adjusting and balancing and functional performance testing for all equipment, controls and economizers.

3. **VERIFICATION**

Decisions about HVAC Selection and Control will have a significant impact on achieving the “2/B.4.1 Energy Use Reduction” requirement. Simulations should be able to transition between different modes of operation in order to predict facility energy use of particular strategies. This iterative process should include simulations reflecting:

- Fully Naturally ventilated mode
- Mixed-Mode (partially natural ventilation, partially cooled, augmented by ceiling fans)
- Fully Mechanically space conditioned mode (only if the two previous options do not fulfill acceptable comfort conditions)

4. **DELIVERABLES**

A. **LEED DOCUMENTATION**

Not required.

B. **DESIGN REVIEW**

a. **Drawings**

Construction drawings and the whole-building energy model should reflect the energy model assumptions and include the HVAC systems specifications as required in these Standards.

b. **Narratives**

Provide a narrative of the proposed sequence of operations and building controls. Describe the modes of operation, setpoints and controls logic for natural ventilation.
2/B.4.2 Energy:: HVAC Selection and Control (Continued)

mode, fan-assist mode, cooling mode, and night purge mode (if applicable) for each key space type (as a minimum for each classroom/ office orientation, labs and transitional spaces.

C. CONSTRUCTION REVIEW
a. Operation Manual
Provide Operations & Maintenance Manuals for all HVAC systems and controls.

b. Commissioning
Provide final commissioning report.

c. Training
UHM personnel must be trained on how to operate and troubleshoot the systems.

D. PERFORMANCE REVIEW
a. Commissioning
Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.

5. RESOURCES
• LEED Reference Guides (http://www.usgbc.org/leed)
• UHM BDPS: Modeling Addendum
• University of Hawaii – Manoa, Mechanical Standards for Consultants
• IECC 2015 (http://www.iccsafe.org/codes-tech-support/codes/2015-i-codes/iecc/)

6. OTHER REQUIREMENTS TO CONSIDER
• 2/B.1.2 COMMISSIONING
• 2/B.3.2.b IEQ:: INDOOR AIR QUALITY:: AFTER CONSTRUCTION
• 2/B.3.5. THERMAL COMFORT
• 2/B.4.1. ENERGY USE REDUCTION
• 2/B.4.8. ENERGY MANAGEMENT SYSTEM
• 3/D POST- OCCUPANCY: PERFORMANCE AND DIAGNOSTICS
2/B. BUILDING PERFORMANCE

2/B.4. ENERGY

2/B.4.3 Electric Lighting Energy

1. REQUIREMENTS

A. CERTIFICATION

Not required.

B. PERFORMANCE

Not Applicable.

C. DESIGN

a. Lighting Power Allowances

Fulfill the requirements from IECC 2015, Section 405.4.2 for whole Lighting Power Allowances for building area method 0.87 W/sqft (School, University), 0.82 W/sqft (Offices). Exceed the Space-by-Space lighting power allowances for classrooms and offices to both achieve 0.6 W/sqft.

DESCRIPTION AND IMPLEMENTATION

The intent of this requirement is to provide high quality and flexible space lighting while increasing lighting energy efficiency use in UHM Buildings.

Electrical lighting must always be designed as a supplement to effective daylighting. Not only light levels are important, but also the distribution of light. Designers should concentrate more light to the task area and then gently manage that light in the surrounding surfaces to create the sense of place that the program calls for. In doing this they will not only create a superior lighting environment but also one that due to its targeted use of light is much more efficient. It is important to note that the effectiveness of lighting is a function of a wide range of performance parameters, not just task illuminance. Designers should take care to avoid overestimating required illuminance levels. An effective lighting design should achieve visual performance and comfort by taking into account task illuminance levels in conjunction with other parameters such as surface brightness, color rendition, and visual variation. The following are requirements on these topics in UHM buildings.
Please refer to 2/B.3.1 Lighting Quantity and Quality to find more information on electric lighting design such as fixture configuration.

**a. Use energy-efficient lamps and ballasts.**

Over the past two decades, significant progress has been made in efficiency improvements to lamps and ballasts, and they are one of the most cost-effective measures for improving energy efficiency in buildings. Efficacy can be evaluated on at least three levels:

- **Lamp efficacy** – which compares the efficacy of different lamps, without considering ballasts.
- **Combined lamp and ballast efficacy** – which includes ballast losses.
- **Luminaire efficacy** – which considers the efficacy of the luminaire system within the context of architectural space. Efficacy metrics can be obtained from manufacturers and other resources.

**b. Maintenance**

Lighting system maintenance should be addressed beginning with the actual luminaire specification. Newer lamp technologies with reduced physical size have driven the design of sleeker, smaller luminaires. These have become correspondingly harder to physically maintain than larger versions simply because appropriate clearances between lamps, reflectors and luminaire housings are often forsaken for aesthetics. It is the lighting designer’s responsibility to specify lighting fixtures that are clearly well-constructed and assembled with maintainability in mind. Accessories to avoid are those that require special tools to remove or that complicate routine maintenance procedures, such as clipped-on external baffles or louvers with sharp edges that snag dust cloths.

### 2. INTEGRATED DESIGN

**A. STRATEGIC PERFORMANCE MEETINGS**

**a. Strategic Meeting #1**

Before the meeting submit preliminary energy modeling to assess alternative fixture configurations in terms of lighting energy use.

Provide a lighting narrative with the following content:

- Describe type of overhead and task lighting fixtures that will be needed.
- Provide initial performance model results for daylight and electric lighting (equivalent to requirement for 2/B. 3.1 Lighting Quality).
b. Strategic Performance Meeting #2
Before the meeting, submit multiple parametric runs comparing options of systems and strategies. Provide energy use and lighting power densities.

c. Strategic Performance Meeting #3
Review the building performance report that includes this topic.

B. COMMISSIONING
Commissioning agent (CA) to be responsible for commissioning and acceptance testing of lighting systems.

Systems must be commissioned to verify proper performance and conformance to the Owner's Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.

3. VERIFICATION:
Use detailed modeling and mock-ups to evaluate alternative electrical lighting and control configurations. Evaluate installed W/sf, illuminance, brightness ratios, uniformity, color rendition. If requirements are demonstrated by running performance modeling, provide computer based simulations results including point by point lighting predictions, illuminance calculations for ceilings and opaque walls.

4. DELIVERABLES
A. LEED DOCUMENTATION
Not applicable.

B. DESIGN REVIEW
a. Drawings
• Determine zone size, switching requirements.
• Submit typical electrical plans, including point-by-point lighting calculations for each representative space type as part of the 50% CD package, with the assumptions for electric lighting during nighttime hours.
2/B.4.3 Energy: Electric Lighting Energy (Continued)

c. Information in schedules and other submissions
- In fixture schedule, for fixtures that fall within open offices and where light emitting surface is visible to occupants, include max candela value for vertical angle of 55 degrees and horizontal angles of either 0 and 90 degrees (when fixtures are orthogonal to desks) or 0, 22.5, 45, 67.5, and 90 degrees (when fixtures are not orthogonal to desks).
- Fixture schedule to include color rendering metrics.

C. CONSTRUCTION REVIEW
a. Commissioning
Include these systems as part of the final commissioning report.

D. PERFORMANCE REVIEW
a. Commissioning
Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.

5. RESOURCES
- UHM BDPS: Modeling Addendum
- IECC 2015 (http://www.iccsafe.org/codes-tech-support/codes/2015-i-codes/iecc/)
- IES Method for Evaluating Light Source Color Rendition (TM-30-15)

6. OTHER REQUIREMENTS TO CONSIDER
- 2/B.1.2 COMMISSIONING
- 2/B 3.1 LIGHTING QUANTITY AND QUALITY

7. TOOLS TO CREATE DOCUMENTATION
Lighting computer program should be used to determine the performance characteristics of the electric lighting systems. Please refer to B/3.1. Building Performance: IEQ: Light Quantity and Quality Section for appropriate tools to evaluate the performance of the different design options.
2/B. BUILDING PERFORMANCE

2/B.4. ENERGY

2/B.4.4. Lighting Controls

1. REQUIREMENTS
   A. CERTIFICATION
   Fulfill the requirements to achieve 1 point from “LEED v4 BD+C EQ Credit 6: Interior lighting” OPTION I: Lighting Control.

   B. PERFORMANCE
   Not Applicable.

   C. DESIGN
   Designs should fulfill the following requirements that are specifically critical for UHM:

   a. Daylight Controls
   Lighting control system to dim or turn off electric ambient lights in response to available daylight (measured by photosensors) while meeting illumination criteria in perimeter zones.

   b. Continuous Dimming
   All fixtures in daylight zones shall have continuous dimming down to at least 10%

   c. Occupancy Sensor Lighting Controls
   Use occupancy sensors for ambient and task lighting. Dim or shut off electric lighting as appropriate when spaces are unoccupied, taking into account occupancy patterns. Lighting in storage areas must be controlled by an occupancy sensor. The sensor must reduce lighting power by at least 50% within 20 minutes of the area becoming unoccupied.

   d. Manual Controls
   Provide manual control of lighting (can be manual override of automated system) in all regularly occupied spaces to include ON/OFF control and continuous dimming. Manual control should be readily accessible and intuitively located near entry doors to the space or in an aisle.
DESCRIPTION AND IMPLEMENTATION

The intent of this Standard is to provide a high level of lighting system control by occupants or automate it as needed in multi-occupant spaces, such as classrooms, to enable adjustments that meet group needs and preferences.

Integrate lighting systems controllability into the overall lighting design, providing ambient and task lighting while managing the overall energy use of the building. Lights are switched on corresponding to the use and layout of the lit areas, in order to avoid lighting a large area if only a small part of it needs light. The following factors and recommendations should be taken into account in UHM buildings.

a. Daylight controls

One of the major benefits of daylighting is the ability to save energy by reducing the use of electrical lighting by dimming or switching. The cost-effectiveness of daylight-based dimming is a function of electricity prices and the cost of dimming systems. One way to improve cost-effectiveness is to right-size the HVAC system by accounting for the reductions in cooling load that result from lower internal heat gains achieved by reducing electrical lighting loads. Another way to improve cost-effectiveness is to use dimming technology further into the occupied space rather than at the perimeter. The rationale for this is that a well-daylit space provides enough daylight at the perimeter so that perimeter luminaires can be switched rather than dimmed. It is more economical to limit use of daylight-harvesting dimming ballasts to luminaires further away from the fenestration, where they will be most effective. A caveat to this approach is that it assumes users at the perimeter will turn off the lights when there is adequate daylight. Consider the use of physical models or computation daylight simulation software such as RADIANCE to optimize integrated daylight designs and establish life cycle costs.

b. Ensure that lighting zones are small enough to provide local control.

Occupants generally prefer manual control of their environments over automatic control. Something as simple as an override to a larger low-voltage switching/dimming system satisfies this desire for direct local control. To limit lighting in unoccupied areas in periods of low occupancy, use smaller lighting zones of about 800 to 1000 sf. Note that task lighting effectively provides local control.
c. Use at least bi-level switching.
Light levels are often greater than required, but occupants do not have the choice to reduce them. Bi-level controls are a low-cost or no-cost add-on (if done at construction) and allow two or three levels. In a typical installation, one switch controls 1/3 of the lamps in a space while the other controls 2/3 of the lamps. This allows for four light levels: off, 1/3, 2/3, and full. Bi-level switching is now required by code in some locations, and may be very appropriate for laboratory spaces, because they are designed to high light levels that many tasks may not even require.

d. Occupancy sensors
Lighting in general and task lights in particular tend to be left on by users. They become part of the visual “landscape,” and users are not consciously aware that they should be turned off when not required. Occupancy sensors are an effective way to reduce energy waste for both ambient and task lighting in laboratories. Dual sensors, composed of both passive infrared and ultrasonic technologies, require the absence of both heat and motion to shut off, minimizing false-triggering problems. To maximize savings, lighting should be controlled separately for each bay. The cost-effectiveness of occupancy controls can be improved if they are also used for laboratory HVAC system control. As in other building types, occupancy sensors are also effective in conference rooms, rest rooms, and other intermittently used rooms.

e. Use sweep-off lighting schedule with manual overrides.
This is appropriate for spaces that tend to be occupied on a predictable schedule, and are not occupied around the clock. Lights are turned off according to preset schedules, based on occupancy patterns.

f. Time control
Time controls should switch on and off automatically in each zone to a preset schedule for light use. Each space with time-switch controls must also have a manual control for lighting reduction and include an override switching device that has:
- A 7-day clock
- 7 different day types/week
- An automatic holiday “shutoff”
2/B.4.4. Energy:: Lighting Controls (Continued)

- Program backup capabilities
- Limits for controlled lighting to be on for less than 2 hours

**g. Passive Infra-Red (PIR) Occupancy sensing**

In areas which are occupied intermittently, occupancy sensors can be used to indicate whether or not anybody is present and switch the light on or off accordingly. Occupant sensors for all spaces must:

- Automatically turn off lights within 30 minutes of all occupancies leaving space
- Be manual on or controlled to automatically turn lighting on to not more than 50% power.
- Include manual control to allow occupants to turn lights off

**h. Light level monitoring**

Light level monitoring consists of switching or dimming artificial lighting to maintain a light level measured by a photocell. Light-reduction controls must allow occupants to reduce connected lighting by at least 50% in a reasonably uniform illumination pattern. Light-reduction methods include:

- Controlling all lamps or luminaires
- Dual switching of alternate rows of luminaires, alternate luminaires or alternate lamps.
- Switching of the middle lamp luminaires independently of the outer lamps.
- Switching each luminaire or lamp

**i. Sign Lighting**

Sign lighting that operates more than one hour per day during daylight hours must be operated with controls that automatically reduce lighting power by at least 65% for one hour after sunset to one hour before sunrise. A notable exception is metal halide, high-pressure sodium, induction, cold cathode and neon sign lighting that automatically reduces lighting power by 30% during the same hours.

All other sign lighting must feature controls that automatically turn the lighting OFF during daylight hours. The controls must automatically reduce the lighting power by at least 30% for period from midnight (or within an hour of the end of building operations, whichever is later) to 6:00 AM (or building opening, whichever is earlier).
2/B.4.4. Energy: Lighting Controls (Continued)

j. Exterior Lighting

Exterior lighting serving uncovered parking areas must be controlled by a photosensor that automatically turns OFF the luminaire during daylight hours. The lighting must also feature an astronomical time switch that turns the luminaires OFF on a schedule.

An exterior luminaire serving an uncovered parking area, if larger than 50 rated input watts and mounted 24 ft. or less above the ground, must be automatically reduced based on occupancy. Specifically, lighting power must be reduced by at least 40% when no activity has been detected in the controlled area after 15 minutes or less. No more than 1500W of lighting power can be controlled by a single controller.

k. Presentation Surfaces

Luminaires installed 3 ft horizontally of any permanently installed presentation surface (such as a whiteboard, chalkboard or projection screen) must be controlled separately from other general lighting in the space. Each control device must be labeled with its light settings. The light settings at a minimum should include those below, depending on the type of presentation system.

- Permanently installed whiteboards: The lighting and controls must be able to light the whiteboard with a vertical light level of an average of 300 lux (about 28 footcandles, rounding up) or higher. The average-to-minimum light level ratio across the whiteboard's full area must be 3:1 or lower.
- Permanently installed screens for front-screen projection units: The lighting and controls must be able to light the screen to a vertical light level of 50 lux (about 5 footcandles, rounding up) or lower. Maximum-to-average light level ratio across the full screen must be 2:1 or lower. Compliance is not met by turning OFF all luminaires in the space.
- Permanently installed screens for rear-projection units: The lighting and controls must be able to light the screen to a vertical light level of 150 lux (about 14 footcandles, rounding up). Maximum-to-average light level ratio across the full screen must be 2:1 or lower. Compliance is not met by turning OFF all the luminaires in the space.
2. **INTEGRATED DESIGN**

   A. STRATEGIC PERFORMANCE MEETINGS
   Lighting controls should be discussed within the Electric Lighting Energy and Design credits.

   B. COMMISSIONING
   Systems must be commissioned to verify proper performance and conformance to the Owner’s Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.

   Commissioning agent (CA) to be responsible for verification that lighting controls have been installed per design and are functioning as intended. This includes occupancy sensors, day lighting controls, multi-level switching, and automatic time clocks. A clear process for commissioning of the electric lighting controls should be defined in response to daylight, especially occupancy and daylight-based controls.

   Include these systems as part of the final commissioning report. Commissioning and calibration of lighting controls are essential if energy savings are to be achieved and maintained. For example, occupancy sensors with sensitivity set too high can fail to save energy, but occupancy sensors with too low a sensitivity or too short a delay time can be annoying or even potentially hazardous to occupants. Similarly, improperly adjusted daylighting controls or improperly located photosensors can dim the lights too low, causing occupants to override them (e.g., by taping over the sensor), or can fail to dim the lights at all.

   During the Lighting System Functional Testing, test lighting control system to ensure control hardware and software are calibrated, adjusted, programmed and in proper working condition per the design and manufacturer’s instructions. This applies to occupancy sensor controls, time-switch controls and daylight responsive controls.

3. **VERIFICATION**
   Lighting controls should be included in all applicable performance models.
4. **DELIVERABLES**

   **A. LEED DOCUMENTATION**

   Submit the documentation required by USGBC for the “**LEED v4 BD+C EQ Credit 6: Interior lighting**” credit for each project phase.

   **B. DESIGN REVIEW**

   1. **Drawings**

      Provide lighting plans that specify the controllability of the systems.

      In a building section view, provide a minimum of independently controlled primary and secondary daylight control zones adjacent to exterior glazing. The primary zone is from the envelope to a depth of one window head height into the space. The secondary zone is from a depth of one window head height to two window head heights into the space.

      In plan view, provide individually controlled daylight zones corresponding to the granularity of manual shade overrides (One per structural bay is often appropriate). Less available daylight as a result of shades being manually deployed should trigger an associated ramping up of electric lights in that area, while in an adjacent area with an automatically retracted shade lights should be dimmed in response to the higher availability of daylight.

      Construction documents must also define the process for commissioning electrical lighting control systems.

   2. **Narratives**

      As a diagram to be included in the lighting controls narrative, Indicate daylight occupancy and manual zones on plans (groups of lights that are controlled together in response to daylight, vacancy/occupancy or manual control). Include lowest possible dimming level for each fixture on fixture schedule.

   3. **Information in schedules and other submissions**

      Fixture schedule to include identification of fixtures dedicated to illuminating task surfaces. Include lowest possible dimming level for each fixture on fixture schedule.
C. CONSTRUCTION REVIEW

a. Commissioning
Include these systems as part of the final commissioning report.

b. Operation Manual
Provide an operation and maintenance manual to UHM staff on the lighting Control systems.

c. Training
UHM personnel must be trained on how to operate and troubleshoot the systems.

D. PERFORMANCE REVIEW

a. Commissioning
Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.

5. RESOURCES
• LEED Reference Guides (http://www.usgbc.org/leed)
• UHM BDPS: Modeling Addendum
• IECC 2015 (http://www.iccsafe.org/codes-tech-support/codes/2015-i-codes/iecc/)

6. OTHER REQUIREMENTS TO CONSIDER
• 2/B.1.2 COMMISSIONING
• 2/B 3.1 LIGHTING QUANTITY AND QUALITY
• 2/B.4.1. ENERGY USE REDUCTION
• 2/B.4.3 ELECTRIC LIGHTING ENERGY AND DESIGN
• 3/D POST- OCCUPANCY: PERFORMANCE AND DIAGNOSTICS
2/B. BUILDING PERFORMANCE

2/B.4. ENERGY

2/B.4.5 Plug Load Reduction

1. REQUIREMENTS
   A. CERTIFICATION
   Not Applicable.

   B. PERFORMANCE
   Not Applicable.

   C. DESIGN
   Designs should fulfill the following requirements that are specifically critical for the Hawaiian Climate:

   a. Maximum Power Density
      Maximum Power density for plug loads: Classroom buildings : 0.5 W/sqft, Office Buildings 0.75 W/sqft. Design Teams are required to pursue programmatic aggregation of building plug loads and public efficiency rather than private individual equipment installation. Encourage best management practices for occupants, preventing by design the over-use of personal equipment as much as possible.

   b. Energy Star Equipment
      Energy Star equipment and appliances are required, where available, for all new purchases. Purchase of low efficiency products is prohibited.

DESCRIPTION AND IMPLEMENTATION
The intent of this requirement is to reduce the electric load from plugged-in equipment where efficiencies are available and controls can be utilized. Plug and process loads (PPLs) account for 33% of U.S. commercial building electricity consumption (McKenney et al. 2010). The design team should develop a plug load reduction plan that identifies all potential plug loads and devices to turn off or sleep when not in use.
2/B.4.5 Energy:: Plug Load Reduction (Continued)

Some of the actions to reduce plug load energy use include:

- Turning off equipment while not in use (manually or automatically)
- Conducting a usage audit to identify equipment that may be turned off or retired.
- Procuring high efficiency equipment.

Plug loads include computers, vending machines and other miscellaneous equipment that are not hard-wired into the building. Examples of plug load reduction strategies include using a timer or smart socket technology on computers, installing energy misers in vending machines and prohibiting unsanctioned personal appliances such as refrigerators, coffee makers and microwaves in individual classrooms or offices.

Hawaii HB 175 (ACT 96) from 2006, directs agencies to purchase ENERGY STAR equipment to the extent possible. ENERGY STAR is the trusted, government-backed symbol for energy efficiency helping buildings save money and protect the environment through energy-efficient products and practices. The ENERGY STAR label makes it easy for consumers to identify and purchase energy-efficient products that offer savings on energy bills without sacrificing performance, features, and comfort. ENERGY STAR brings a proven energy management strategy to save money for repair and renovation, hiring of new faculty, new construction, and other core activities.

For product categories that have ENERGY STAR rated products available, procurement efforts should be focused on products with an ENERGY STAR rating consistent with leading practice. For those goods already in use across the system, available energy conservation features shall be ENERGY STAR enabled.

2. INTEGRATED DESIGN
   A. STRATEGIC PERFORMANCE MEETINGS:
      a. Strategic Performance Meeting #1
         Establish maximum equipment power density goals to be used in performance models. Discuss strategies to minimize equipment energy use.

      b. Strategic Performance Meeting #2
         Review fulfillment of this credit's requirements in the final design and coordinate with the construction team.
c. Strategic Performance Meeting #3
Review the building performance report that includes this topic.

B. COMMISSIONING:
Not Applicable

3. VERIFICATION:
Actual equipment power densities to be used in performance models. Analyze schedules and implications of other relevant modeling assumptions.

4. DELIVERABLES
A. LEED DOCUMENTATION
Not required.

B. DESIGN REVIEW
a. Narratives
Submit a plug load reduction plan, including the inventory of equipment and the identification of the responsible party for implementation of the plan.

C. CONSTRUCTION REVIEW
a. Narratives or Other Submittals
Provide a list along with proof of purchase for all equipment and appliances. The list must include the brand, product name and model number. Compliance will be verified through the ENERGY STAR website.

D. PERFORMANCE REVIEW
a. Commissioning
Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.

5. OTHER REQUIREMENTS TO CONSIDER
• 2/B.4.1. ENERGY USE REDUCTION
2/B. BUILDING PERFORMANCE

2/B.4. ENERGY

2/B.4.6. Peak Load Control

1. REQUIREMENTS
   A. CERTIFICATION

   Fulfill the requirements to achieve 2 points from “LEED v4-BD+C EA Credit 4: Demand response”.

   B. PERFORMANCE
   Not Applicable.

   C. DESIGN
   Designs should fulfill the following requirements that are specifically critical for the Hawaiian Climate:

   a. Demand Reduction System

   All building projects contain automatic systems, such as demand limiting or load shifting, that are capable of reducing electrical peak demand of the building by not less than 10% exclusive of any demand reduction that may be provided by standby power generation. This peak load reduction requirement is lowered to 5% if all the mechanical equipment efficiencies meet the ENERGY STAR requirements.

DESCRIPTION AND IMPLEMENTATION
The intent of this requirement is to reduce dependence on purchased energy sources during peak demand hours through overall reduction and load shifting.

Load management, also known as demand side management (DSM), is the process of balancing the supply of electricity on the network with the electrical load by adjusting or controlling the load rather than the power station output. This can be achieved by direct intervention of the utility in real time, by the use of frequency sensitive relays triggering the circuit breakers (ripple control), by time clocks, or by adjusting energy use to the utility special tariffs. Load management allows utilities to reduce demand for electricity during peak usage times, which can, in turn, reduce costs by eliminating the need for peaking power plants.
2/B.4.6. Energy: Peak Load Control (Continued)

2. INTEGRATED DESIGN
   A. STRATEGIC PERFORMANCE MEETINGS
      a. Strategic Performance Meeting #2
         Review fulfillment of this credit’s requirements in the final design and coordinate
         with the construction team.
      
         b. Strategic Performance Meeting #3
         Review the building performance report that includes this topic.
   
   B. COMMISSIONING
   Systems must be commissioned to verify proper performance and conformance
   to the Owner’s Project Requirements (OPR) and UHM personnel must be trained
   as part of the commissioning process.
   
3. VERIFICATION:
   Not required
   
4. DELIVERABLES
   A. LEED DOCUMENTATION
   Submit the documentation required by USGBC for the “LEED v4 BD+C EA Credit
   4: Demand response” credit for each project phase.
   
   B. DESIGN REVIEW
      a. Narratives
      Submit a peak load control plan describing how this requirement would be fulfilled,
      including the inventory of equipment and the end uses that would be part of the
      system and the identification of the responsible party for implementation of the
      plan.
   
   C. CONSTRUCTION REVIEW
      a. Operation Manual
      Provide a PDF of the manual or plan provided to staff on the Peak Load Control
      System addressing how to control and operate the system.
      
         b. Commissioning
         Include this system as part of the final commissioning report.
2/B.4.6. Energy: Peak Load Control (Continued)

c. Training
UHM personnel must be trained on how to operate and troubleshoot the systems.

D. PERFORMANCE REVIEW
a. Commissioning
Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.
2/B. BUILDING PERFORMANCE

2/B.4. ENERGY

2/B.4.7. Renewables

1. REQUIREMENTS

A. CERTIFICATION

Fulfill the requirements to achieve 3 points (10% renewable energy produced from predicted total building annual energy cost) from “LEED v4 BD+C EA Credit 5: Renewable energy production”

B. PERFORMANCE

Designs should fulfill the following requirements that are specifically critical for the Hawaiian Climate:

a. Enhanced Renewable Energy Production

Use on-site renewable energy sources for electricity production for at least 20% of the expected annual electricity use** of the building without the renewable system.

** Note that LEED Certification specifies a percentage of total building annual energy cost, whereas these Standards (according to ACT 99 requirements) specifies a percentage of expected annual electricity use.

C. DESIGN

Not Applicable.

DESCRIPTION AND IMPLEMENTATION

The intent of this requirement is to encourage on-site energy generation from renewable resources. Use alternative energy sources and supply systems to reduce the building’s total energy load and minimize environmental impacts of burning fossil fuels such as air pollution and global warming. Evaluate possibilities for the use of renewable energy (such as solar water heaters, geothermal heating and cooling systems, and solar walls).
Most renewable power technologies do not produce greenhouse gases and emit far less pollution than burning oil and coal to generate electricity. With the exception of biomass technologies, the fuel source is free, and indigenous renewable energy sources also represent a secure and stable source of energy.

The proposed buildings should incorporate energy generation integrated within the building design. Examples would be photovoltaics used as shade structures for pedestrians or rain screens. Campus wide initiatives for renewable energy generation are designed to supplement this requirement, not replace.

ACT 99 superseeds Executive Policy EP . 4-202- UH System Sustainability (that requiring projects to provide energy generation of 10% by 2020, 20% by 2025, 30% by 2030, and 40% by 2035). ACT 99 requires that the University of Hawaii to establish a collective goal of becoming net-zero with respect to energy use, producing as much energy as the system consumes across all campuses, by January 1, 2035.

a. Solar Power

Photovoltaic (PV) panels should be oriented to collect sun and large enough to meet the building’s electric load. At tropical latitudes, because the sun is high, tilt can be more important that orientation. PV arrays may be:

- Integrated with the building and even add R-value to the envelope;
- Mounted on racks and attached to the building’s structure
- Affixed to short stand-off mounts above the weather envelope
- Integrally mounted to the structure, with PV’s serving as the building skin
- Integrated as a part of other materials, such as roofing tiles, spandrel panels, shading devices, or glazing

Roof design strategies that support the use of PV into roof ridges oriented east-west, larger roofs sloped toward the south, with smaller roofs sloped to the north, and chimneys, plumbing vents, and other roof penetrations located on non-south oriented roofs.

b. Wind Power

Harnessing Wind energy to UHM is beneficial to achieve its energy conservation goals. Unlike any type of centralized power generation, wind energy is completely renewable and available all year round.
2/B.4.7. Energy:: Renewables (Continued)

There are two wind farms available for UHM to harnessing power in the Islands, located in the island of Maui and The Big Island of Hawaii. Both wind farms produce about 30-35 megawatts of clean energy back to the grid, which HECO distributes around the Islands. With the potential for more Wind farm installation, UHM could investigate the potential for micro turbines.

Use energy storage technologies to complement Solar and wind power intermittent availability. The design team should evaluate the feasibility and potential size on a case by case basis.

All projected energy generation should be calculated using a predictive energy performance model.

To reduce hazardous situations for utility service technicians, the utility may require the renewable generation system inverter to automatically shut off generation during a power outage of power feeding the building from the grid. In this situation, a renewable generation system might not be capable of functioning as a backup power supply in case of a grid outage.

2. INTEGRATED DESIGN
   A. STRATEGIC PERFORMANCE MEETINGS
      a. Strategic Performance Meeting #1.
      Provide initial net zero feasibility study. (Please refer to 2/A. 2 Site and Program Analysis). The net zero performance study should establish the amount of renewable energy to be generated on site in order to achieve net zero performance should be developed.

      b. Strategic Performance Meeting #2
      Review the net zero feasibility study with updated and more detailed energy use results before the construction phase starts. Review fulfillment of this credit’s requirements in the final design and coordinate with the construction team.

      c. Strategic Performance Meeting #3
      Review the building performance report that includes this topic.
2/B.4.7. Energy:: Renewables (Continued)

B. COMMISSIONING
Systems must be commissioned to verify proper performance and conformance to the Owner’s Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.

Commissioning agent (CA) to be responsible for commissioning and acceptance testing of renewable energy systems.

3. VERIFICATION:
Use the same calculations or methodology used for estimating the Building Energy Use Intensity to show that the installed system will supply the required percentage of the load.

4. DELIVERABLES
A. LEED DOCUMENTATION
Submit the documentation required by USGBC for the “LEED v4 BD+C EA Credit 5: Renewable energy production” credit for each project phase.

B. DESIGN REVIEW
a. Drawings
Construction drawings must include the location of the system, details for installation and calculations showing the renewable energy systems performance.

b. Narratives
Describe the approach to maximize renewable energy production.

c. Simulations (Analysis and Results)
Provide simulation results that estimate total energy produced by month and percentage of energy used that is provided by renewable sources..

C. CONSTRUCTION REVIEW
a. Commissioning
Include these systems as part of the final commissioning report.
D. PERFORMANCE REVIEW

a. Performance Reports
Complete a performance assessment report describing achievement of energy production target (Please refer to “3/D Post-Occupancy: Performance Diagnostics and Maintenance” for further description of this requirement).

b. Commissioning
Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.

5. RESOURCES
- LEED Reference Guides (http://www.usgbc.org/leed)
- UHM BDPS: Modeling Addendum
- IECC 2015 (http://www.iccsafe.org/codes-tech-support/codes/2015-i-codes/iecc/)
- NREL PV Watts Calculator (http://pvwatts.nrel.gov)

6. OTHER REQUIREMENTS TO CONSIDER
- 2/B.1.2 COMMISSIONING
- 2/B.4.1. ENERGY USE REDUCTION
- 3/D POST- OCCUPANCY: PERFORMANCE AND DIAGNOSTICS
2/B. BUILDING PERFORMANCE

2/B.4. ENERGY


1. REQUIREMENTS
   A. CERTIFICATION
      Not Applicable.

   B. PERFORMANCE
      Not Applicable.

   C. DESIGN
      Designs should fulfill the following requirements that are specifically critical for Post-Occupancy building performance verification process and required by UH-Executive Policy, EP 4.202.

      a. Advanced Energy Management System
      Install an advanced Energy Management System (EMS) and coordinate it to include and display the information collected in all energy meters installed in the building according to the requirement 2/A.4.8 Energy Measurement of these Standards.

DESCRIPTION AND IMPLEMENTATION
The intent of this requirement is to provide control, accountability, and optimization of building energy performance. This Energy Management System (EMS) should be used to reduce energy by tracking the real time performance of the system and manages demand response to reduce overall demand and peak loads.

A EMS is computer-based system that automatically monitors and controls a range of building energy services. The essence of Building Management Systems is in the control technologies, which allow integration, automation, and optimization of all the services and equipment that provide services and manages the environment of the building concerned.
The meter data management system should be capable of electronically storing energy meter monitoring systems and submeter data and creating reports showing calculated hourly, daily, monthly, and annual energy consumption for each measurement device and submeter and provide alarming notification capabilities as needed to support the requirements of the Energy Use Efficiency Plan for Operation.

The EMS should include the following features:

- Temperature and ventilation control of spaces
- Temperature and status monitoring and data storage for all HVAC equipment input and output points and outdoor air temperature and humidity points
- An alarm interface to notify operators when conditions are out of range
- A web based operating graphical user interface for remote access to all data, graphics, operating schedules and trend reporting
- Sensors to trend outdoor air temperature
- Sensors to monitor and trend equipment status for all equipment with motors greater than 1/2 hp
- Indication and trending of damper and valve commanded position
- Sensors to monitor building electrical and natural gas demand and consumption
- Sensors to monitor indoor and outdoor CO2

Monitoring capabilities of the EMS should allow for comparison between various types of building loads throughout all spaces of the building. This information is valuable and can be used to manage and optimize energy use. By trending and monitoring the building operation, any deviation from the design operation can be identified and corrected before an impact on occupant comfort and energy performance of the building is created. Building performance can also be optimized by longer-term trending, observation of performance characteristics, and benchmarking performance against expected operation.

Usage and correct operation are vital for effective results: staff must be provided with a manual and training on how to operate the EMS and utilize the information. Education of users; improved systems-design user-friendliness, and the provision of relevant instructions and information are all critical to enable theory to translate into practice, and for potential effectiveness and savings to be realized.

2. INTEGRATED DESIGN
A. STRATEGIC PERFORMANCE MEETINGS:
   a. Strategic Performance Meeting #2
      Review fulfillment of this credit's requirements in the final design and coordinate
      with the construction team.
   b. Strategic Performance Meeting #3
      Review the building performance report that includes this topic.

B. COMMISSIONING:
   Systems must be commissioned to verify proper performance and conformance
   to the Owner’s Project Requirements (OPR) and UHM personnel must be trained
   as part of the commissioning process.

   Commissioning agent (CA) to be responsible for ensuring that any and all energy
   management and control systems (EMCSs) perform the sequence of operations
   and provide trend logs per design. Also establish that sensors are calibrated.

3. VERIFICATION:
   Not required.

4. DELIVERABLES
   A. LEED DOCUMENTATION
      Not required.

   B. DESIGN REVIEW
      a. Drawings
      Construction drawings must include the Energy Management System and required
      features. The specifications should include a list of all the sensors installed
      according to the requirement 2/B.4.8 Energy Measurement and actuators (devices
      to be controlled). It should also specify the protocol for communication between
      the sensors, actuators and the computer (controller) and the requirements for the
      graphic user interface (GUI).
C. CONSTRUCTION REVIEW
   a. Operation Manual
      Provide a PDF of the manual or plan provided to staff on the EMS addressing how
      the operator interface works.

   b. Commissioning
      Include these systems as part of the final commissioning report.

   c. Training
      UHM personnel must be trained on how to operate and troubleshoot the EMC
      system.

D. PERFORMANCE REVIEW
   a. Commissioning
      Update the systems manual with any modifications or new settings, and give
      the reason for any modifications from the original design. Define methods for
      improving operations and maintenance.

5. OTHER REQUIREMENTS TO CONSIDER
   • 2/B.1.2  COMMISSIONING
   • 2/B.4.9. ENERGY USE MEASUREMENT
   • 2/B. 3. WATER:: WATER MANAGEMENT SYSTEM
   • 3/D POST- OCCUPANCY: PERFORMANCE AND DIAGNOSTICS
2/B. BUILDING PERFORMANCE

2/B.4. ENERGY


1. REQUIREMENTS
   
   A. CERTIFICATION
   
   Fulfill the requirements to achieve 1 point from the “LEED v4 BD+C EA Credit 3: Advanced energy metering” credit.

   B. PERFORMANCE
   
   Not Applicable.

   C. DESIGN
   
   Designs should fulfill the following requirements that are specifically critical for Post-Occupancy building performance verification process and required by UH-Executive Policy, EP 4.202.

   a. Enhanced Energy Metering*
   
   In case the requirements to achieve LEED compliance do not fulfill the needs for UHM to monitor building performance and energy use over time once the building is occupied, all projects should install permanent energy metering for the following:

   • All whole-building energy sources used by the building or submeters that can be aggregated to provide building-level data representing total building energy consumption (electricity and chilled water as a minimum).
   • End uses including as a minimum: lighting, plug loads, HVAC and renewable energy (depending on project scope for Group 2 Projects).

* Note that these requirements seem to be equivalent to the ones implied in the certification compliance. The intention of this performance requirement is to make sure that critical end uses are metered, independently from the percentage of the total annual energy consumption of the building that they represent. In addition, the energy metering characteristics described in the “description and Standard” section below are more advanced than the ones outlined in the LEED Reference Guide.
DESCRIPTION AND IMPLEMENTATION

The intent of this requirement is to support energy management and identify opportunities for additional energy savings by tracking building-level energy use, system-level energy use. This also fulfills the requirements included in the University of Hawaii Executive Policy 4.202 on System Sustainability to establish reporting mechanisms to track energy conservation and energy efficiency.

Ongoing monitoring of any new or retrofitted building is integral to its energy efficient performance: an important part of ensuring the sustainable performance of an energy efficient building is establishing that it continues to perform as designed. To better facilitate that performance, energy consumption data must be captured and retained.

The energy metering must have the following characteristics.

- Be fully coordinated with the energy management system (EMS)
- Meter readings should be automated.
- Meters must be permanently installed and transmit data to a remote location.
- The system must be capable of collecting and storing all meter data for at least 36 months.
- All meters in the system must be capable of reporting daily, monthly, and annual energy use.
- Electricity meters must record both consumption and demand. Whole-building electricity meters should record the power factor, if appropriate.

2. INTEGRATED DESIGN

A. STRATEGIC PERFORMANCE MEETINGS

a. Strategic Performance Meeting #2

Review fulfillment of this credit’s requirements in the final design and coordinate with the construction team.

b. Strategic Performance Meeting #3

Review the building performance report that includes this topic.

B. COMMISSIONING

Systems must be commissioned to verify proper performance and conformance to the Owner’s Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.

Commissioning agent (CA) to be responsible for ensuring that any and all energy management and control systems (EMCSs) perform the sequence of operations and provide trend logs per design. Also establish that sensors are calibrated.

3. **VERIFICATION:**
   
Not required.

4. **DELIVERABLES**
   
A. **LEED DOCUMENTATION**
   
Submit the documentation required by USGBC for the “**LEED v4 BD+C EA Credit 3: Advanced energy metering**” credit for each project phase.

B. **DESIGN REVIEW**
   
a. **Drawings**
   
   • Construction drawings must include a riser diagram highlighting metering of all systems.
   
   • Construction drawings must include the Energy Measuring Equipment and required features. The specifications should include a list of all the sensors (measurements to be taken throughout the building) and be coordinated with the Energy Management System included as required in 2/A.4.7. **Energy Management System** of these Standards.

b. **Other submittals**
   
Create and submit a monitoring plan that includes:
   
1. Monitoring Narrative
2. Proposed Monitoring Locations
3. Electrical Monitoring Equipment

C. **CONSTRUCTION REVIEW**
   
a. **Operation Manual**
   
Provide a PDF of the Operation and Maintenance manual to staff.

b. **Commissioning**
   
Include these systems as part of the final commissioning report.

c. Training
UHM personnel must be trained on how to operate and troubleshoot the systems.

D. PERFORMANCE REVIEW
a. Commissioning
Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.

6. RESOURCES
• LEED Reference Guides (http://www.usgbc.org/leed)

7. OTHER REQUIREMENTS TO CONSIDER
• 2/B.1.2 COMMISSIONING
• 2/B.4.8. ENERGY:: ENERGY MANAGEMENT SYSTEM
• 3/D POST- OCCUPANCY: PERFORMANCE AND DIAGNOSTICS
Oahu sustains a population of about 1 million people. Fresh groundwater is naturally filtered and is a vital, yet limited resource in many parts of Hawaii. Responsible design that manages water use and collection saves money and extends the lifetime of Hawaii’s reserves.

Sustainable design dictates that water and its relationships to building design, development, and operations are managed carefully. The principle of sustainable building seeks to increase the value derived from water resources by designing and operating UHM structures more efficiently.

Hawaii’s limited aquifer capacity and large run off to adjacent oceans means a careful and considerate approach to water management is a necessity. Sound water management involves maintaining water quality, re-using water where possible and controlling the storm water.

Buildings should incorporate features to reduce the amount of potable water consumed. Features should include efficient fixtures, condensate capture and/or graywater systems. To achieve overall water conservation goals, it is important to limit the use of potable water for non-potable purposes. On-site water reclamation and reuse should be encouraged and facilitated wherever possible.

Objectives of these Standards:

- Preserve site watersheds and groundwater aquifers.
- Conserve and reuse storm water
- Maintain appropriate level of water quality on the site and in the building(s).
- Reduce potable water consumption
- Reduce off-site treatment of wastewater

Each project should encompass responsibilities beyond the walls of the building and beneficially tie into the infrastructure. Catchment from roofs and hardscape will be directed to storage, recharge or swales on or near the site.
All new projects on University of Hawaii at Manoa campus are now required to achieve LEED Silver certification and strive for LEED Gold (*UHM Executive Policy EP.4.202*). It is important then to mention that all Prerequisites included in LEED v4 should be fulfilled, even if not directly included in these Standards as requirements.

For this “Water” section, all LEED Prerequisites are fulfilled with the Standards requirements, which are more strict or demanding than the LEED Prerequisites themselves. These include:

- *LEED v4 NC- WE Prerequisite 1: Outdoor water use reduction*
- *LEED v4 NC WE Prerequisite 2: Indoor water use reduction*
- *LEED v4 NC WE Prerequisite 3: Building-level water metering*
2/C. WATER

2/C.1. USE REDUCTION

2/C.1.1. Site

1. REQUIREMENTS

A. CERTIFICATION

Fulfill the requirements to achieve a minimum of 1 point (50% reduction compared to baseline) from “LEED v4- NC WE Credit 1: Outdoor water use reduction”.

B. PERFORMANCE

Not Applicable.

C. DESIGN

Designs should fulfill the following requirements that are specifically critical for the Hawaiian Climate:

a. Water Budget For Landscape

Develop a water budget in accordance with the U.S. Environmental Protection Agency's WaterSense Water Budget Tool including both the Landscape Water Requirement (LWR) and the Landscape Water Allowance (LWA). The allowance is based on the landscaped area, evapotranspiration rates specific to Hawaii climates and historical rainfall.

b. Native Landscape

Refer to the UHM Landscape Masterplan for requirements on landscape area to be biodiverse planting of native plants and adapted plants.

c. Irrigation System Control

Any irrigation system for the project site must be controlled by a qualifying smart controller that uses evapotranspiration (ET) and weather data to adjust irrigation schedules or an on-site rain or moisture in the soil that automatically shuts the system off after a predetermined amount of rainfall or sensed moisture in the soil.
DESCRIPTION AND IMPLEMENTATION

The intent of this Standard is to reduce and optimize potable water use for irrigation. A water budget is a reasonable estimate of the amount of irrigation water required for a specific landscape over a given time interval.

In the State of Hawaii the patterns of precipitation can vary greatly from coastal areas to mountain tops. When the demand of potable water increases, more water is drawn to accommodate that demand and underground aquifers can be stressed to the point of creating water shortages. To minimize the shortage problem, the irrigation should be designed with water efficient irrigation systems if landscape irrigation is necessary, or, do not install permanent irrigation systems for landscaping. Specify water-efficient native (or adapted) climate-tolerant plantings, high-efficiency irrigation controllers, rainfall sensors or use captured rain or reclaimed water.

2. INTEGRATED DESIGN

A. STRATEGIC PERFORMANCE MEETINGS

a. Strategic Performance Meeting #1
Submit a narrative describing water needs for the site as part of the water budget analysis developed in the preliminary analysis phase. (Please refer to 2/A.2 Site and Program Analysis for specific requirements on this analysis).

b. Strategic Performance Meeting #2
Review fulfillment of this credit's requirements in the final design and coordinate with the construction team.

c. Strategic Performance Meeting #3
Review the building performance report that includes this topic.

B. COMMISSIONING
Commissioning agent (CA) to be responsible for commissioning and acceptance testing of irrigation systems.

Systems must be commissioned to verify proper performance and conformance to the Owner’s Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.
3. **VERIFICATION:**
   Not required.

4. **DELIVERABLES**

   **A. LEED DOCUMENTATION**
   Submit the documentation required by USGBC for the “LEED v4 BD+C WE Credit 1: Outdoor water use reduction” credit for each project phase. In addition, submit the following:

   **B. DESIGN REVIEW**
   
   **a. Drawings**
   - Construction drawings must include all outputs of the U.S. Environmental Protection Agency’s WaterSense Water Budget Tool including both the Landscape Water Requirement (LWR) and Landscape Water Allowance (LWA).
   - Construction drawings must include complete landscape drawings identifying irrigation system components and specifications for efficient irrigation equipment.

   **b. Narratives**
   If no permanent irrigation will be provided, provide a letter signed by the landscape architect certifying that permanent irrigation systems have not been specified and that only drought resistant or native or adapted plants have been specified in these areas. Letter must clearly state that no irrigation, manual or otherwise, will be needed in these areas after plants are established, and the species of plants that have been specified.

   **c. Information in schedules and other submissions**
   The outputs should reflect the landscape plans provided. The water budget should be reflected in the landscaping plan and in specifications for efficient irrigation equipment.

   **C. CONSTRUCTION REVIEW**
   
   **a. Commissioning**
   Include these systems as part of the final commissioning report.
D. PERFORMANCE REVIEW
   a. Commissioning
      Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.

5. RESOURCES
   • LEED Reference Guides (http://www.usgbc.org/leed)
   • HI- CHPS Criteria 2012- WE.P1 Outdoor Water Budget and Irrigation System Performance
   • LEED Reference Manual: Water Credit 1: Outdoor Water Use Reduction
   • U.S. Environmental Protection Agency’s WaterSense Water Budget Tool (http://www.epa.gov/WaterSense/nhspecs/wb_data_finder.html)
   • ASHRAE 189.1- 2014 Standard for the Design of High Performance Green buildings

6. OTHER REQUIREMENTS TO CONSIDER
   • 2/B.1.2 COMMISSIONING
   • 2/D.1.1 STORMWATER
2/C. WATER

2/C.1. WATER USE REDUCTION

2/C.1.2. Building

1. REQUIREMENTS

   A. CERTIFICATION

   Fulfill the requirements to achieve a minimum of 1 point (25% reduction compared to baseline) from “LEED v4- NC WE Credit 2: Indoor water use reduction”.

   Fulfill the requirements to achieve a minimum of 2 points from “LEED v4-NC-v4 WEc3: Cooling tower water use”.

   B. PERFORMANCE

   Not Applicable.

   C. DESIGN

   Designs should fulfill the following requirements that are specifically critical for the Hawaiian Climate:

   a. Maximize Water Efficiency

   Provide a water efficiency narrative that supports the water budget analysis developed in the analysis phase in order to maximize water efficiency.

DESCRIPTION AND IMPLEMENTATION

The intent of this Standard is to maximize water efficiency within buildings to reduce the burden on the local water supply, aquifers, and wastewater treatment systems. Buildings should minimize the use of Domestic Water by ensuring a proper selection of plumbing fixtures, equipment, and fittings to minimize end use of domestic water while conserving water quality and availability.

This Standard also fulfills the requirements included in the University of Hawaii Executive Policy 4.202 on System Sustainability to establish best management practices methods for rainwater/stormwater storage, recharge and reuse on the campus.
One of the most important ways to begin using water more efficiently is to create a water balance. A water balance shows the sources and uses of water on a site. The objective is to show where and how water is being used, what the sources are, and how much water is being disposed of. In new facilities, a balance can help designers plan equipment layouts and identify opportunities for greater efficiency. In existing facilities, it can help building managers identify leaks, other losses, and possible misuses.

a. Water Using Equipment

The first step is to document all major water-using equipment and processes at the site and usage amounts. The water quality required for each use can also be included, as well as information about the local climate, such as monthly averages for evapotranspiration rate, relative humidity, temperature, and precipitation. The second step is to determine whether known purchases equal known usage. If these two are in balance, the next step is to look for opportunities for greater efficiency in each major usage category and determine whether water from one process can be used elsewhere cost effectively. If purchases and usage do not balance, however, more investigation is needed. Often, the chief culprit is a lack of information. A thorough review can help building managers fill in any missing information and discover the source of the imbalance.

Select plumbing fixtures and fittings that evince state-of-the-art capabilities in terms of water conservation—especially those that perform above the standards already mandated by federal, state and local laws. Use low flow toilets, preferably dual-flush, that have been tested and rated to function reliably. Use waterless or very low flow (0.5 gallons per flush) urinals. Use lavatory faucets with flow restrictors for a maximum rate of 0.5 gallons per minute (GPM), or use metering faucets at 0.25 gallons per cycle. Use low-flow kitchen faucets. Use low-flow showerheads.

b. Cooling Towers

Both cooling towers and evaporative condensers should be equipped with makeup water meters, conductivity controllers and overflow alarms and efficient drift eliminators that reduce drift to maximum of 0.002% of recirculated water volume for counterflow towers and 0.005% of recirculated water flow for cross-flow towers.
2/C.1.2. Water:: Use Reduction:: Building (continued)

No once-through cooling with potable water for any equipment or appliances that reject heat.

2. **INTEGRATED DESIGN**

   **A. STRATEGIC PERFORMANCE MEETINGS**

   **a. Strategic Performance Meeting #1**

   Before the meeting, submit a water efficiency narrative draft that discusses the following:
   - Identify appropriate alternative water sources.
   - Locate collection or storage areas.
   - Include a process or cooling loop for all equipment.
   - Include a vacuum system.
   - Include condensate and chilled water return systems.

   Discuss the water budget analysis developed in the preliminary analysis phase. (Please refer to credit 2/A.2 Site and Program Analysis of these Standards for specific requirements on this analysis).

   **b. Strategic Performance Meeting #2**

   Review fulfillment of this credit’s requirements in the final design and coordinate with the construction team.

   **c. Strategic Performance Meeting #3**

   Review the building performance report that includes this topic.

   **B. COMMISSIONING**

   Commissioning agent (CA) to be responsible for commissioning and acceptance testing of plumbing, domestic and process water pumping and mixing and service water heating systems.

   Systems must be commissioned to verify proper performance and conformance to the Owner’s Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.
3. **VERIFICATION:**
   
   Not required.

4. **DELIVERABLES**

   **A. LEED DOCUMENTATION**
   
   Submit the documentation required by USGBC for both “LEED v4 BD+C WE Credit 2: Indoor water use reduction” and “LEED v4 BD+C WEc3: Cooling tower water use” credits for each project phase. In addition, submit the following:

   **B. DESIGN REVIEW**
   
   **a. Drawings**
   
   Construction drawings must include a plumbing fixture schedule that reflects the indoor water calculations.

   **b. Narratives**
   
   Submit a water efficiency narrative that discusses the following:
   - Identify any processes that can use water from other processes or that can supply water to processes.
   - Select equipment with water-saving features.

   **C. CONSTRUCTION REVIEW**
   
   **a. Commissioning**
   
   Include these systems as part of the final commissioning report.

   **D. PERFORMANCE REVIEW**
   
   **a. Performance Reports**
   
   Complete a performance assessment report describing achievement of water use target (Please refer to “3/D Post-Occupancy: Performance Diagnostics and Maintenance” for further description of this requirement).

   **b. Commissioning**
   
   Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.
5. **RESOURCES**
   - LEED Reference Guides ([http://www.usgbc.org/leed](http://www.usgbc.org/leed))
   - HI- CHPS Criteria 2012- WE.C1 Indoor Water Use Reduction
   - U.S. Environmental Protection Agency’s WaterSense Water Budget Tool

6. **OTHER REQUIREMENTS TO CONSIDER**
   - 2/A.2 SITE AND PROGRAM ANALYSIS
   - 2/B.1.2 COMMISSIONING
2/C. WATER

2/C.2. WATER WASTE REDUCTION

1. REQUIREMENTS

A. CERTIFICATION
Not Applicable.

B. PERFORMANCE
Not Applicable.

C. DESIGN
Designs should fulfill the following requirements that are specifically critical for the Hawaiian Climate:

a. Potable Water Reduction For Sewage Conveyance
Projects must reduce the use of potable water (fixture and fitting aggregate water consumption) for building sewage conveyance by 20% through the utilization of water-efficient fixtures.

DESCRIPTION AND IMPLEMENTATION
The intent of this Standard is to reduce the amount of water leaving the project site, either by way of the surrounding landscape or waste water treatment facilities, through management and recycling/reuse.

Use water-efficient fixtures and reclaimed water to reduce the amount of potable water used for sewage conveyance. Only those sources that produce black water (such as toilet and urinals, are included in this requirement. Reclaimed water (tertiary treated wastewater) and/or greywater generated and treated on-site are suitable for flushing toilets and urinals, which typically produce the largest amounts of wastewater in UHM buildings.

This Standard fulfills the requirements included in the University of Hawaii Executive Policy 4.202 on System Sustainability to establish best management practices methods for wastewater management to reduce effluent discharge into local surface
To quantify water use reduction, list each fixture that produces blackwater, the amount of daily uses, number of occupants and total water use. Calculate Daily water use per fixture using the following equation:

\[
\text{Daily Water Use} = (\text{Flow rate}) \times (\text{Duration}) \times (\text{Occupants}) \times (\text{Daily Uses})
\]

Sum Daily Water Volumes for each fixture to find Total Daily Volume. Multiply the Total Daily Volume by the number of school days for Total Annual Volume. Subtract the amount of reclaimed water used to find Total Potable Water Used for Sewage Conveyance.

Provide shut-off capabilities (manual or automatic) for water supply to all urinals and water closets to prevent water leakage when unoccupied. Use infrared faucet sensors and delayed action shut-off or automatic shut-off valves.

Technical Strategies for Water Waste Reduction include:

- Rainwater use. Collect and use rainwater for landscape irrigation, urban gardening, toilet/urinal flushing, roof cooling (for uninsulated roofs), and for other purposes as appropriate. A rainwater catchment system should be designed with a water storage capacity for sewage conveyance and irrigation in typical years under average conditions. Oversizing water storage will be costly and undersizing storage may simply result in a system that is too small to significantly offset potable water consumption. In addition, mold growth and accumulation of bacteria should be avoided.

- Condensate Recovery: In Hawaii, mechanical space conditioning is likely to generate significant quantities of condensate, as warm humid air is cooled and dried for temperature and humidity control. The condensate from air conditioners, dehumidifiers, and refrigeration units can provide facilities with a steady supply of relatively pure water for many processes. Laboratories are excellent sites for this technology because they typically require dehumidification of a large amount of 100% outside air. Condensate should not be considered potable because it can contain dissolved contaminants and bacteria. However, because biocide is added to cooling towers, condensate is an excellent option for cooling tower make-up.
2/C.2. Water Waste Reduction (continued)

- Recycled water: The Hawai‘i State Department of Health Recycled Water Guidelines include irrigation, flushing toilets, urinals, and sanitary sewers where permitted by the applicable county plumbing code, and cooling in air conditioning systems as suitable use of recycled water depends on its quality and application method.

2. INTEGRATED DESIGN
   A. STRATEGIC PERFORMANCE MEETINGS
      a. Strategic Performance Meeting #2
      Review fulfillment of this credit’s requirements in the final design and coordinate with the construction team.

   B. COMMISSIONING
   Commissioning agent (CA) to be responsible for commissioning and acceptance testing of plumbing, domestic and process water pumping and mixing and service water heating systems.

   Systems must be commissioned to verify proper performance and conformance to the Owner’s Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.

3. VERIFICATION:
Not required.

4. DELIVERABLES
   A. LEED DOCUMENTATION
   Not required.

   B. DESIGN REVIEW
      a. Drawings
      Construction drawings must include a plumbing fixture schedule that reflects the indoor water calculations and identify shut-off capabilities for restrooms facilities.

   C. CONSTRUCTION REVIEW
      a. Commissioning
      Include these systems as part of the final commissioning report.
D. PERFORMANCE REVIEW
Not required.

5. RESOURCES
• HI- CHPS Criteria 2012- WE.C2 Reduce Potable Water Use for Sewage Conveyance
• HI- CHPS Criteria 2012- WE.C5 Irrigation System Commissioning
• Recycled Water Guidelines:: Volume II: Recycled Water Projects, Prepared by Hawai‘i State Department of Health, Wastewater Branch
2/C. WATER

2/C.3. WATER MANAGEMENT SYSTEM

1. REQUIREMENTS
   A. CERTIFICATION
      Not Applicable.

   B. PERFORMANCE
      Not Applicable.

   C. DESIGN
      Designs should fulfill the following requirements that are specifically critical for
      Post-Occupancy building performance verification process and required by UH-

   a. Advanced Water Management System
      Install a Water Management System (WMS) on all equipment and systems on all
      indoor and outdoor water uses.
      Coordinate the WMS to include and display the information collected in all
      water meters installed in the building according to the requirement 2/B.4 Water
      Measuring Equipment of these Standards.

DESCRIPTION AND IMPLEMENTATION
The intent of this Standard is to fulfill the requirements included in the University
of Hawaii Executive Policy 4.202 on System Sustainability to establish reporting
mechanisms to track water conservation and water efficiency. A water management
system (WMS) must monitor both indoor and outdoor water usage to detect leaks and
improve efficiency.

When selecting a water management system take into consideration how the system
could be integrated with an energy management system. A water management
system can potentially save significant water but only if staff understands its report
and how to operate it.
2/C.3. Water Management System (continued)

The meter data management system should be capable of electronically storing water meter, monitoring systems and submeter data and creating reports showing calculated hourly, daily, monthly, and annual water consumption for each measurement device and submeter and provide alarming notification capabilities as needed to support the requirements of the Water Use Efficiency Plan for Operation.

2. INTEGRATED DESIGN

A. STRATEGIC PERFORMANCE MEETINGS
   a. Strategic Performance Meeting #2
      Review fulfillment of this credit's requirements in the final design and coordinate with the construction team.

   b. Strategic Performance Meeting #3
      Review the building performance report that includes this topic.

B. COMMISSIONING

Commissioning agent (CA) to be responsible for commissioning and acceptance testing of water measurement devices.

   Systems must be commissioned to verify proper performance and conformance to the Owner's Project Requirements (OPR) and UHM personnel must be trained as part of the commissioning process.

3. VERIFICATION:
   Not required.

4. DELIVERABLES

A. LEED DOCUMENTATION
   Not required.

B. DESIGN REVIEW
   a. Drawings
      Construction drawings must include the Water Management System and required features. The specifications should include a list of all the sensors installed according to the requirement 2/B.4 Water Measuring Equipment and actuators
2/C.3. Water Management System (continued)

(devices to be controlled). It should also specify the protocol for communication between the sensors, actuators and the computer (controller) and the requirements for the graphic user interface (GUI).

C. CONSTRUCTION REVIEW

a. Operation Manual
Provide a PDF of the manual or plan provided to staff on the WMS addressing how the operator interface works; and proof of purchase and installation.

b. Commissioning
Include these systems as part of the final commissioning report.

D. PERFORMANCE REVIEW

a. Commissioning
Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.

5. OTHER REQUIREMENTS TO CONSIDER
• 2/B.1.2 COMMISSIONING
• 2/B.4.8. ENERGY MANAGEMENT SYSTEM
• 2/C.4. WATER USE MEASUREMENT
2/C. WATER

2/C.4. WATER USE MEASUREMENT

1. REQUIREMENTS

   A. CERTIFICATION
   Fulfill the requirements to achieve a minimum of 1 point from “LEED v4 BD+C WEc4: Water metering”.

   B. PERFORMANCE
   Not Applicable.

   C. DESIGN
   Designs should fulfill the following requirements that are specifically critical for Post-Occupancy building performance verification process and required by UH-Executive Policy, EP 4.202.

   a. Enhanced Water Measurement
   In case the requirements to achieve LEED compliance do not fulfill the needs for UHM to monitor building performance and water use over time once the building is occupied, all projects should install permanent water metering for the whole-building or submeters that can be aggregated to provide building-level data representing total building water use and other critical end uses such as irrigation and indoor plumbing fixtures as a minimum.

   * Note that these requirements seem to be equivalent to the ones implied in the certification compliance. The intention of this performance requirement is to make sure that critical water uses are metered, independently from the percentage of the total water use of the building that they represent. In addition, the water metering characteristics described in the “Water Management System” are more advanced than the ones outlined in the LEED Reference Guide.

DESCRIPTION AND IMPLEMENTATION
The intent of this Standard is also to support water management and identify opportunities for additional water savings by tracking water consumption.

See applicable LEED Reference Guide.
2/C.4. Water Use Measurement (continued)

2. INTEGRATED DESIGN
   A. STRATEGIC PERFORMANCE MEETINGS
      a. Strategic Performance Meeting #2
         Review fulfillment of this credit’s requirements in the final design and coordinate
         with the construction team.

      b. Strategic Performance Meeting #3: Review the building performance report
         that includes this topic.

   B. COMMISSIONING
   Commissioning agent (CA) to be responsible for commissioning and acceptance
   testing of water measurement devices.

   Systems must be commissioned to verify proper performance and conformance
   to the Owner’s Project Requirements (OPR) and UHM personnel must be trained
   as part of the commissioning process.

3. VERIFICATION:
   Not required.

4. DELIVERABLES
   A. LEED DOCUMENTATION
   Submit the documentation required by USGBC to achieve the LEED credit
   mentioned above. In addition, submit the following:

   B. DESIGN REVIEW
      a. Drawings
      Construction drawings must include the Water Measuring Equipment and
      required features. The specifications should include a list of all the sensors
      (measurements to be taken throughout the building) and be coordinated with the
      Water Management System included as required in 2/B.3. Water Management
      System of these Standards.
b. Narratives
Create and submit a monitoring plan that includes:
  1. Monitoring and Datalogging Narrative
  2. Proposed Monitoring and Datalogging Locations
  3. Water Monitoring Equipment

C. CONSTRUCTION REVIEW
a. Commissioning
Include these systems as part of the final commissioning report.

D. PERFORMANCE REVIEW
a. Commissioning
Update the systems manual with any modifications or new settings, and give the reason for any modifications from the original design. Define methods for improving operations and maintenance.

4. OTHER REQUIREMENTS TO CONSIDER
  • 2/B.1.2 COMMISSIONING
  • 2/C.3. WATER MANAGEMENT SYSTEM
2/D. SITE

The intent of site sustainability is to support efficient use of campus land and resources, protect environmentally sensitive lands, reduce heat island effect, minimize site light pollution, maximize pervious surfaces, retain native and biodiverse vegetation and manage on-site storm water through reuse, infiltration or evapotranspiration.

Landscaping also has value as a psychological benefit. Even tall narrow plantings, when viewed from inside, especially on higher floors, can produce a benefit to users, connecting them with nature and potentially reducing reflected glare and direct gains.

As described in the UHM Landscape Masterplan (5.3.3 Guidelines Related To Environmental Aspects Of Planting Design), campus plantings should be increased to improve environmental benefits to the campus community. Additional benefits from plantings in terms of building performance include:

- Reducing urban heat island
- Regulating local climate through moderation of heat and evapotranspiration
- Contributing to global climate regulation by sequestering CO2
- Reducing cooling demand of buildings through shading
- Slowing and reducing the volume of storm water runoff
- Improving storm water quality through infiltration and filtering sediment
- Controlling soil erosion
- Reducing air pollution through sequestering polluting gases and particulates.

All Group 1 projects on University of Hawaii at Manoa campus are now required to achieve LEED Silver certification and strive for LEED Gold (UHM Executive Policy EP.4.202). It is important then to mention that all Prerequisites included in LEED v4 should be fulfilled, even if not directly included in these Standards as requirements.

For this “Site” section, such Prerequisites not specifically part of these Standards include:

- LEED v4 SS Prerequisite 1: Construction activity pollution prevention
2/D. SITE

2/D.1. LANDSCAPE

2/D.1.1. Stormwater

1. REQUIREMENTS
   A. CERTIFICATION
   
   Fulfill the requirements to achieve a minimum of 2 points from “LEED NC-v4 SSc4: Rainwater management”.

   B. PERFORMANCE
   
   Not Applicable.

   C. DESIGN
   
   For all site design decisions affecting stormwater management refer to the guidelines included in the UH Manoa Landscape Master Plan and UH Manoa Drainage, Sewer and Water Master Plans. Designs should fulfill the following requirements that are specifically critical for the Hawaiian Climate:

   a. UHM Specific Stormwater Management

   The fulfillment of this requirement should be pursued in conjunction with the UHM Landscape Masterplan (SECTION 5 - Landscape System Guidelines, 5.1 Landscape Guidelines for Drainage Systems) and the Drainage, Sewer and Water Master Plan.

   DESCRIPTION AND IMPLEMENTATION

   The intent of this Standard is to manage stormwater after construction to control erosion and runoff, recharge local aquifers, and maintain the quality of receiving waters.

   As described in the UH Manoa Landscape Masterplan, at the beginning of a new project, the design team should perform a geotechnical exploration of the soils within the project area. The geotechnical report should include analysis of the limit of soils with low permeability, infiltration tests, groundwater levels and depth to bedrock.
2. INTEGRATED DESIGN
   A. STRATEGIC PERFORMANCE MEETINGS
      a. Strategic Performance Meeting #2
         Review fulfillment of this credit’s requirements in the final design and coordinate with the construction team.

   B. COMMISSIONING
      Not Applicable

3. VERIFICATION
   Not required

4. DELIVERABLES
   A. LEED DOCUMENTATION
      Submit the documentation required by USGBC to achieve the LEED credit mentioned above. in addition, submit the following:

   B. DESIGN REVIEW
      a. Drawings
         • Include the geotechnical report as part of the drawing submittals.
         • Clearly identify them in the drawing plans.

   C. CONSTRUCTION REVIEW
      a. Narratives or Other Submittals
         Provide a site-specific Stormwater Pollution Prevention Plan (SWPPP) and pictures identifying measures taken throughout construction.

   D. PERFORMANCE REVIEW
      Not required.

5. RESOURCES
   • LEED Reference Guides (http://www.usgbc.org/leed)

6. OTHER REQUIREMENTS TO CONSIDER
   • 2/C.1.1. STORMWATER
2/D. SITE

2/D.1. LANDSCAPE

2/D.1.2. Erosion

1. REQUIREMENTS

A. CERTIFICATION

Not Applicable.

B. PERFORMANCE

Not Applicable.

C. DESIGN

For all site design decisions affecting site erosion refer to the guidelines included in the UH Manoa Landscape Master Plan and UH Manoa Drainage, Sewer and Water Master Plans.

Designs should fulfill the following requirements that are specifically critical for the Hawaiian Climate:

a. Erosion And Sedimentation Control Plan

Design and implement a site-specific erosion and sedimentation control (ESC) plan for all construction activities associated with the project.

DESCRIPTION AND IMPLEMENTATION

The intent of this Standard is to prevent soil erosion before, during, and after construction by controlling storm water runoff and wind erosion.

Control erosion and the transport of soil and other pollutants off the site during construction. Protect hillsides using adequate erosion control measures such as hydro seeding, erosion control blankets, and/or sedimentation ponds to collect runoff. Consider silt fencing, sediment traps, construction phasing, stabilization of slopes, and maintaining and enhancing vegetation and ground cover.

The site-specific erosion and sedimentation control (ESC) plan must describe the measures implemented, conform to the erosion and sedimentation requirements of the 2012 U.S. Environmental Protection Agency (EPA) Construction General Permit.
(CGP) and incorporate the use of best management practices in compliance with the U.S. EPA's National Pollutant Discharge Elimination System (NPDES). The erosion and sedimentation control plan should also meet the following objectives:

- Prevent soil loss by wind and water erosion, including protecting topsoil by stockpiling for reuse.
- Prevent transport of sediment and particulate matter to storm sewers or receiving waters and/or to air.
- Eliminate or reduce off-site discharge of construction waste.
- Prevent pollution of the air with dust and particulate matter.

2. INTEGRATED DESIGN
   A. STRATEGIC PERFORMANCE MEETINGS
      a. Strategic Performance Meeting #2
      Review fulfillment of this credit's requirements in the final design and coordinate with the construction team.

   B. COMMISSIONING
      Not Applicable

3. VERIFICATION:
   Not required

4. DELIVERABLES
   A. LEED DOCUMENTATION
      Not required.

   B. DESIGN REVIEW
      a. Drawings
      Construction drawings must include the site runoff control measures.

      b. Other Submittals
      Submit the site-specific erosion and sedimentation control (ESC) plan.
C. CONSTRUCTION REVIEW
Not required.

D. PERFORMANCE REVIEW
Not required.

5. RESOURCES
   • LEED Reference Guides (http://www.usgbc.org/leed)

6. OTHER REQUIREMENTS TO CONSIDER
   • 2/C.1.1. STORMWATER
1. REQUIREMENTS

A. CERTIFICATION

Fulfill the requirements to achieve 2 points from “LEED v4 BD+C SSc5: Heat Island Reduction”.

B. PERFORMANCE

Not Applicable.

C. DESIGN

Designs should fulfill the following requirements that are specifically critical for the Hawaiian Climate:

a. On Site Tree Protection

Protect existing mature and heritage trees on site prior to, and during construction to preserve their historic value, and the high level of air quality, water, quality, social and global environmental benefits they provide. Follow the guidelines included in the UHM Landscape Masterplan (6.3 Policy For Tree Protection During Construction).

DESCRIPTION AND IMPLEMENTATION

Heat Islands are particularly problematic in tropical climates. The intent of this Standard is to prevent the effects of heat islanding on microclimate and human and wildlife habitat. Minimize the effect of heat-absorbing materials used for site hardscape, walls and roofs through careful materials choices. Consider the effects on adjacent buildings and landscaping.

See applicable LEED Reference Guide.

a. Tree protection

Follow the guidelines included in the UHM Landscape Masterplan (6.3 Policy For Tree Protection During Construction).
2/D.2. Heat Island (Continued)

- Designate a tree protection zone around mature (greater than 12” trunk diameter or 20 years of age) and heritage tree trunks to protect their root system and canopy. The zone includes a fence that is either 10 x the diameter of the tree or 10 feet, whichever is greater, and must be in place prior to any site work and remain until occupancy.
- No new trenching or construction may occur within the tree protection zone.
- No mature or heritage trees may be removed, (unless an arborist determines they are dangerous or diseased), unless replanted on the same site, if they are not detrimental to the foundation.

2. INTEGRATED DESIGN
   A. STRATEGIC PERFORMANCE MEETINGS
      a. Strategic Performance Meeting #2
         Review fulfillment of this credit’s requirements in the final design and coordinate with the construction team.

   B. COMMISSIONING
      Included as a requirement for all lighting systems. See 2/B.4.3. Electric Lighting Energy

3. VERIFICATION:
   Not required

4. DELIVERABLES
   A. LEED DOCUMENTATION
      Submit the documentation required by USGBC to achieve the LEED credit mentioned above for each project phase. In addition, submit the following:

   B. DESIGN REVIEW
      a. Drawings
         Construction drawings, likely the landscaping plans, must provide the results described, and identify mature and heritage trees on the site. The plans must show the required tree protection measures and instructions on when and how long they must be implemented.
C. CONSTRUCTION REVIEW
Not required.

D. PERFORMANCE REVIEW
Not required.

5. RESOURCES
- LEED Reference Guides (http://www.usgbc.org/leed)
2/D. SITE

2/D.3. LIGHT POLLUTION REDUCTION

1. REQUIREMENTS
   
   A. CERTIFICATION
   
   Fulfill the requirements to achieve 1 point from “LEED v4 BD+C SSc6: Light pollution reduction”.

   B. PERFORMANCE
   
   Not Applicable.

   C. DESIGN
   
   Designs should fulfill the following requirements that are specifically critical for the Hawaiian Climate:

   a. Limit Interior Lighting Contribution
   
   Design interior lighting so that the angle of maximum candela from each interior luminaire as located in the building intersects opaque building interior surfaces and not exit through the windows (only if work is in scope for Group 2 projects).

   b. IESNA Practices
   
   Meet but do not exceed the lighting limits in IESNA Recommended Practices.

   c. UHM Exterior Lighting Guidelines
   
   Follow the guidelines for exterior lighting included in UHM Landscape Masterplan (5.5.14 Exterior Lighting)

DESCRIPTION AND IMPLEMENTATION

The intent of this Standard is to minimize the impact of site illumination on the nocturnal environment. Light pollution is a broad term used to describe unwanted or unnecessary nighttime illumination, classified as light trespass, glare and skyglow.

Design site lighting and select lighting styles and technologies to have minimal impact off-site and minimal contribution to sky glow. Provide adequate lighting for safety,
incorporating excellence in design and energy efficiency and compliance with dark-sky principles.

Plants and animals depend on Earth’s daily cycle of light and dark rhythm to govern life-sustaining behaviors such as reproduction, nourishment, sleep and protection from predators. According to the Dark Sky Association, scientific evidence suggests that artificial light at night has negative and deadly effects on many creatures including amphibians, birds, mammals, insects and plants.

Specify IESNA cutoff or IESNA Full cutoff for all exterior-site and building-mounted lighting fixtures greater than 13 watts. Specify IESNA Full cutoff for fixtures greater than 70 watts. Cutoff and full cutoff fixtures may not be the adjustable type.

This section also requires adherence to the exterior lighting power allowances of ASHRAE/IES Standard 90.1 Addendum in an attempt to balance visual needs with the desire to eliminate unnecessary light. Exterior luminaires must have controlled backlight and uplight emissions plus glare control so as to minimize “light pollution.” Exterior luminaires must meet BUG (backlight, uplight, glare) ratings, referenced in IES TM-15, Addendum A. Section 5.3.6.

See applicable LEED Reference Guide.

2. INTEGRATED DESIGN
   A. STRATEGIC PERFORMANCE MEETINGS
      a. Strategic Performance Meeting #
         Review fulfillment of this credit’s requirements in the final design and coordinate with the construction team.

   B. COMMISSIONING
      Not Applicable

3. VERIFICATION:
   Simulations should show predicted illuminances at ground level. Refer to 2/B.3.1 Light Quantity and Quality for a more detailed description of available tools to use for this analysis.
4. DELIVERABLES

A. LEED DOCUMENTATION
Submit the documentation required by USGBC for the “LEED v4 BD+C SSc6: Light pollution reduction” credit for each project phase.

B. DESIGN REVIEW
   a. Drawings
   Construction drawings for interior lighting should provide building section(s) diagramming the angle of the maximum candela value. The lighting plans should also show that all non-emergency lighting is on a programmable timer that turns lighting off during non-operable hours and that provides manual override capability for after hours use.

   b. Information in schedules and other submissions
   Include exterior lighting fixture schedule with manufacturers and model numbers, and manufacturers spec sheets, with a clear description of the specified lamps, wattage, IESNA cutoff classification, Light Loss Factor and shielding accessories for each fixture.

   c. Simulations (Analysis and Results)
   Provide a photometric site plan (that shows at least 10’ beyond the property line) that includes the average, maximum, and minimum illuminances for each area. Horizontal illuminances at ground level on a minimum 10ft by 10ft grid with the property line clearly marked in bold. Indicate the location and mounting height of all site building mounted exterior fixtures.

C. CONSTRUCTION REVIEW
   Not required.

D. PERFORMANCE REVIEW
   Not required.

5. RESOURCES
   • LEED Reference Guides (http://www.usgbc.org/leed)
2/D.3. Light Pollution Reduction (continued)

6. **OTHER REQUIREMENTS TO CONSIDER**
   - 2/B.3.1 LIGHT QUANTITY AND QUALITY
   - 2/B.4.3. ELECTRIC LIGHTING ENERGY
The high cost of living in Hawaii is not without reason—land and buildings are relatively more expensive due to its location, which limits access to, as well as the tangible limits of, native natural resources. Efficient design reduces material use and minimizes waste and pollutions while maximizing performance. Using less material and sustainable construction practices decreases initial costs, disposal costs, waste, and environmental burden. This is especially relevant given the carbon miles associated with transporting materials to Hawaii. Furthermore, using non-toxic building materials and furnishings creates a healthy indoor environment for occupants.

From a sustainability perspective, the best building materials are those that are long-lived, least disruptive to harvest, ship, and install, and are also easiest and safest to maintain and reuse. Sustainable design at all stages of building development, including plans to recycle or reuse construction and demolition waste, can help to further alleviate the pressure on our natural resources and our landfills.

For the true realization of high performance building we must consider the full life cycle of a building, which requires the selection of materials of low life cycle cost, low toxicity material preferably locally sourced, climate responsive (high albedo (reflectance), thermal mass properties, durability) and glare reducing both internally and externally.

Appendix of these Standards includes the review of successful LEED case studies in Hawaii. The goal was to identify all, if any, limitations that seem to be specific to green building design in Hawaii. This document recognizes that some of the LEED credits are not easy to achieve in Hawaii or not applicable to the Hawaiian conditions, such as MR.c4.2 Materials reuse, Recycled content over 20%, MR.c5.2 Regional materials over 20%, and MR.c6 Rapidly renewable materials.

In addition to providing a sense of permanence, design the building with materials and systems that require less maintenance, appropriate to the tropical climate including the effects of sun, rain, salt air, humidity, and termites.
Objectives:
- Reduce consumption and depletion of material resources, particularly nonrenewable resources.
- Minimize the life-cycle impact of materials on the environment.
- Enhance indoor environmental quality.
- Minimize waste generated from construction, renovation, and demolition of buildings.
- Minimize waste generated during building occupancy.
- Increase potential for material reuse.

All Group 1 projects on University of Hawaii at Manoa campus are now required to achieve LEED Silver certification and strive for LEED Gold (UHM Executive Policy EP.4.202). It is important then to mention that all Prerequisites included in LEED v4 should be fulfilled, even if not directly included in these Standards as requirements.

For this “Building Materials” section, such Prerequisites not specifically part of these Standards include:

*MR Prerequisite 1: Storage and collection of recyclables*

*MR Prerequisite 2: Construction and demolition waste management planning*
2/E. BUILDING MATERIALS

2/E.1. SOURCE CERTIFIED

1. REQUIREMENTS
   A. CERTIFICATION
      Fulfill the requirements to achieve 1 point from “LEED v4 BD+C MR Credit 3: Building product disclosure and optimization - sourcing of raw materials”.

   B. PERFORMANCE
      Not Applicable.

   C. DESIGN
      Not Applicable.

DESCRIPTION AND IMPLEMENTATION
The intent of this Standard is to encourage the use of products and materials for which life cycle information is available and that have environmentally, economically, and socially preferable life cycle impacts. Project teams are encouraged to select products verified to have been extracted or sourced in a responsible manner.

See applicable LEED Reference Guide.

2. INTEGRATED DESIGN
   A. STRATEGIC PERFORMANCE MEETINGS
      a. Strategic Performance Meeting #2
         Review fulfillment of this credit’s requirements in the final design and coordinate with the construction team.

   B. COMMISSIONING
      Not Applicable

3. VERIFICATION:
   Not required
4. **DELIVERABLES**
   A. **LEED DOCUMENTATION**
      Submit the documentation required by USGBC for the LEED credit mentioned above for each project phase.

   B. **DESIGN REVIEW**
      Not required.

   C. **CONSTRUCTION REVIEW**
      Not required.

   D. **PERFORMANCE REVIEW**
      Not required.

5. **RESOURCES**
   - LEED Reference Guides ([http://www.usgbc.org/leed](http://www.usgbc.org/leed))
2/E. BUILDING MATERIALS

2/E.2. CONSTRUCTION AND DEMOLITION WASTE

1. REQUIREMENTS
   A. CERTIFICATION
   Fulfill the requirements to achieve 2 points from “LEED v4 BD+C MR Credit 5: Construction and demolition waste management”.

   B. PERFORMANCE
   Not Applicable.

   C. DESIGN
   Not Applicable.

DESCRIPTION AND IMPLEMENTATION

The intent of this Standard is to divert as much construction and demolition waste from landfills and incarceration facilities as possible by recovering, reusing and recycling materials.

This requirement is feasible in all parts of Hawaii. Construction waste management can even take place through sub-contractors sorting the waste into multiple dumpsters. Recycling construction and demolition materials reduces demand for virgin resources and diminishes the need for landfill space.

See applicable LEED Reference Guide.

2. INTEGRATED DESIGN
   A. STRATEGIC PERFORMANCE MEETINGS
      a. Strategic Performance Meeting #2 (or #1 in Group 3 Projects)
      Review fulfillment of this credit’s requirements in the final design and coordinate with the construction team.

   B. COMMISSIONING
   Not Applicable
3. **VERIFICATION:**
Not required

4. **DELIVERABLES**
   
   **A. LEED DOCUMENTATION**
   Submit the documentation required by USGBC for the “LEED v4 BD+C MR Credit 5: Construction and demolition waste management” credit for each project phase.

   **B. DESIGN REVIEW**
   Not required.

   **C. CONSTRUCTION REVIEW**
   Not required.

   **D. PERFORMANCE REVIEW**
   Not required.

5. **RESOURCES**
   
   • LEED Reference Guides (http://www.usgbc.org/leed)
   
   
   • Minimizing Construction and Demolition Waste in Hawaii. Clean Hawaii Center (http://hawaii.gov/health/environmental/compliance/sb_library/c_and_d_waste_min.pdf)
2/E. BUILDING MATERIALS

2/E.3. DESIGN FOR DISASSEMBLY

1. REQUIREMENTS
   A. CERTIFICATION
      Not Applicable.
   
   B. PERFORMANCE
      Not Applicable.
   
   C. DESIGN
      Designs should fulfill the following requirements that are specifically critical for UHM Buildings:

      a. Disassembly Plan
         Provide UHM with a Disassembly Plan that has the method of disassembly for major systems during renovations and end-of-life, and the properties of major materials and components.

DESCRIPTION AND IMPLEMENTATION
The intent of this Standard is to optimize environmental performance and economic savings through decision-making based on operational life, and to provide spaces that are adaptable, durable, and flexible. Design teams should design major systems with differing functions and lifespan to promote disentanglement and provide access to, and types of connections that allow, disassembly.

Incorporate interior or exterior design options into the project to facilitate building adaptability. Consider site planning and building configuration to accommodate future additions and alterations. The UHM buildings serve as a primary facility in conducting its teachings, research and management throughout the whole campus. With its 11 colleges with different academic programs, it’s able to accommodate 20,005 of its total student population and 1,272 of its full time faculty. Depending on the program department of the campus, each building facilitates as classrooms, laboratories and office spaces. With the long term use of each of the buildings in mind, the facilities
management is not just looking for ways to increase the performance of the external building but the spaces within the buildings as well.

By implementing ‘Smart Growth,’ UHM is looking to increase its enrollment rate with high quality programs that will be filled by students who are looking for emerging fields and degrees needed for the economy of the future. Such growth in development requires a plan for flexible programs, and UHM must assess how to maximize the facilities and spaces efficiently as possible. One of the main solutions to this challenge is the installation of modular wall and partition systems inside the buildings.

2. INTEGRATED DESIGN
   
   A. STRATEGIC PERFORMANCE MEETINGS
   
   a. Strategic Performance Meeting #2
      
      Review fulfillment of this credit’s requirements in the final design and coordinate with the construction team.

   B. COMMISSIONING
      
      Not Applicable

3. VERIFICATION:
   
   Not required

4. DELIVERABLES
   
   A. LEED DOCUMENTATION
      
      Not required.

   B. DESIGN REVIEW
      
      a. Drawings
         
         • Construction drawings must show major system designs to promote disentanglement. It may be necessary to provide additional sketches or drawings that are not typically found in plan sets.
         
         • Construction drawings must show system connection drawings.
C. CONSTRUCTION REVIEW

a. Narratives/ other submittals
Submit a Disassembly Plan. At a minimum the plan should include:

• An explanation of reusable, recyclable, and durable component and material selections.
• An explanation of modular components and dimensions, and plug-and-play components for major systems.
• A plan for major component repairs and replacements, potential conversions, and end-of-life disassembly.
• A complete set of as-built drawings if different than design drawings.
  An inventory of chemical and mechanical properties as appropriate, ratings and warranties, manufacturer name and date and production.
• A description of strategies to minimize the use of coatings and composites.
• A plan to allow for movement of workers and equipment in the deconstruction phase.

D. PERFORMANCE REVIEW
Not required.

5. RESOURCES
• LEED Reference Guides (http://www.usgbc.org/leed)
• HI-CHPS Criteria 2012- II.C10: Design for Adaptability, Durability and Disassembly