# Indoor Environmental Quality



Americans spend on average 90% of their time indoors where the U.S. Environmental Protection Agency reports that levels of pollutants may run two to five times—and occasionally more than 100 times—higher than outdoor levels[1]. Similarly, the World Health Organization reported in its Air Quality Guidelines for Europe, Second Edition[2] that most of an individual's exposure to many air pollutants comes through inhalation of indoor air. Many of these pollutants can cause health reactions in the estimated 17 million Americans who suffer from asthma and 40 million who have allergies, thus contributing to millions of days absent from school and work. Outbreaks of Legionnaires' disease and sick building syndrome confirm the relationship of indoor air quality to the occupant health.

Over the past twenty years, research and experience has improved our understanding of what is involved in attaining high Indoor Environmental Quality (IEQ), and revealed manufacturing and construction practices that can prevent many IEQ problems from arising. The use of better products and practices has reduced potential liability for design team members and building owners. The results are increased market value for buildings with exemplary IEQ and greater productivity for the occupants. In a case study included in the 1994 publication Greening the Building and the Bottom Line, the Rocky Mountain Institute cites how improved indoor environmental quality improved worker productivity by 16%, netting a rapid payback on the increased capital investment.

Preventing IEQ problems is generally much less expensive than identifying and solving them after they occur. One practical way to prevent IEQ problems from arising is to specify materials that release fewer and less harmful chemical compounds. Evaluation of the properties of the adhesives, paints, carpets, composite wood products and furniture and specifying those materials with low levels of potentially irritating off-gassing can reduce occupant exposure. Scheduling of deliveries and sequencing construction activities can reduce material exposure to moisture and absorption of off-gassed contaminants. Protection of air handling systems during construction and a building flush-out prior to occupancy further reduces potential for problems arising during the operational life of a building.

Using higher ratios of filtered outside air, increasing ventilation rates, managing moisture, and controlling the level of contaminants in the cleaning substances used can provide optimal air quality for building occupants. Installation of automatic sensors and controls to maintain proper temperature, humidity, and rates of outdoor air introduced to occupied spaces also plays a key role in maintaining optimal air quality. Use of sensors to alert building maintenance staff to potential Indoor Air Quality (IAQ) problems such as carbon dioxide ($CO_2$) build-up in an occupied space can also effectively balance energy and IEQ issues.

Occupant well-being can be improved by providing views to the exterior and by providing daylighting. In addition, providing occupants with the ability to control their personal thermal environment can reduce hot/cold complaint calls and generally raise occupant satisfaction levels which can lead to increases in productivity.

The joint efforts of the owner, building design team, contractors, subcontractors and suppliers are integral to providing a quality indoor environment.

### Overview of LEED® Prerequisites and Credits

**EQ Prerequisite 1**
Minimum IAQ Performance

**EQ Prerequisite 2**
Environmental Tobacco Smoke (ETS) Control

**EQ Credit 1**
Outdoor Air Delivery Monitoring

**EQ Credit 2**
Increased Ventilation

**EQ Credit 3.1**
Construction IAQ Management Plan—During Construction

**EQ Credit 3.2**
Construction IAQ Management Plan—Before Occupancy

**EQ Credit 4.1**
Low-Emitting Materials—Adhesives & Sealants

**EQ Credit 4.2**
Low-Emitting Materials—Paints & Coatings

**EQ Credit 4.3**
Low-Emitting Materials—Carpet Systems

**EQ Credit 4.4**
Low-Emitting Materials—Composite Wood & Agrifiber

**EQ Credit 5**
Indoor Chemical & Pollutant Source Control

**EQ Credit 6.1**
Controllability of Systems—Lighting

**EQ Credit 6.2**
Controllability of Systems—Thermal Comfort

**EQ Credit 7.1**
Thermal Comfort—Design

**EQ Credit 7.2**
Thermal Comfort—Verification

**Overview of LEED® Prerequisites and Credits (continued)**

**EQ Credit 8.1**
Daylighting & Views—
Daylight 75% of Spaces

**EQ Credit 8.2**
Daylighting & Views—
Views for 90% of Spaces

## Indoor Environmental Quality Credit Characteristics

**Table 1** shows which credits were substantially revised for LEED-NC Version 2.2, which credits are eligible to be submitted in the Design Phase Submittal, and which project team members are likely to carry decision-making responsibility for each credit. The decision-making responsibility matrix is not intended to exclude any party, rather to emphasize those credits that are most likely to require strong participation by a particular team member.

**Table 1:** EQ Credit Characteristics

| **Credit** | Significant Change from LEED-NC v2.1 | Design Submittal | Construction Submittal | Owner Decision-Making | Design Team Decision-Making | Contractor Decision-Making |
|---|---|---|---|---|---|---|
| **EQp1**: Minimum IAQ Performance | * | * | | | * | |
| **EQp2**: Environmental Tobacco Smoke (ETS) Control | | * | | * | * | |
| **EQc1**: Outdoor Air Delivery Monitoring | * | * | | | * | |
| **EQc2**: Increased Ventilation | * | * | | | * | |
| **EQc3.1**: Construction IAQ Management Plan, During Construction | * | | * | | | * |
| **EQc3.2**: Construction IAQ Management Plan, Before Occupancy | * | | * | | | * |
| **EQc4.1**: Low-Emitting Materials, Adhesives & Sealants | | | * | | * | * |
| **EQc4.2**: Low-Emitting Materials, Paints & Coatings | | | * | | * | * |
| **EQc4.3**: Low-Emitting Materials, Carpet Systems | * | | * | | * | |
| **EQc4.4**: Low-Emitting Materials, Composite Wood & Agrifiber | | | * | | * | * |
| **EQc5**: Indoor Chemical & Pollutant Source Control | * | * | | | * | |
| **EQc6.1**: Controllability of Systems, Lighting | * | * | | | * | |
| **EQc6.2**: Controllability of Systems, Thermal Comfort | * | * | | | * | |
| **EQc7.1**: Thermal Comfort, Design | * | * | | | * | |
| **EQc7.2**: Thermal Comfort, Verification | * | * | | * | * | |
| **EQc8.1**: Daylighting & Views, Daylight 75% of Spaces | * | * | | | * | |
| **EQc8.2**: Daylighting & Views, Views for 90% of Spaces | * | * | | | * | |

Required

# Minimum IAQ Performance

## Intent

Establish minimum indoor air quality (IAQ) performance to enhance indoor air quality in buildings, thus contributing to the comfort and well-being of the occupants.

## Requirements

Meet the minimum requirements of Sections 4 through 7 of ASHRAE 62.1-2004, Ventilation for Acceptable Indoor Air Quality. Mechanical ventilation systems shall be designed using the Ventilation Rate Procedure or the applicable local code, whichever is more stringent.

Naturally ventilated buildings shall comply with ASHRAE 62.1-2004, paragraph 5.1.

## Potential Technologies & Strategies

Design ventilation systems to meet or exceed the minimum outdoor air ventilation rates as described in the ASHRAE standard. Balance the impacts of ventilation rates on energy use and indoor air quality to optimize for energy efficiency and occupant health. Use the ASHRAE 62 Users Manual for detailed guidance on meeting the referenced requirements.

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|
| Prerequisite 1 | | | | | |

## Summary of Referenced Standard

**ASHRAE Standard 62.1-2004: Ventilation For Acceptable Indoor Air Quality**

American Society of Heating, Refrigerating and Air-Conditioning Engineers

www.ashrae.org

(800) 527-4723

"The purpose of this standard is to specify minimum ventilation rates and indoor air quality that will be acceptable to human occupants and are intended to minimize the potential for adverse health effects. This standard is intended for regulatory application to new buildings, additions to existing buildings and those changes to existing buildings that are identified in the body of the standard. This standard applies to all indoor or enclosed spaces that people may occupy, except where other applicable standards and requirements dictate larger amounts of ventilation than this standard. Release of moisture in residential kitchens and bathrooms, locker rooms, and swimming pools is included in the scope of this standard. Additional requirements for laboratory, industrial, and other spaces may be dictated by workplace and other standards, as well as by the processes occurring within the space. This standard considers chemical, physical, and biological contaminants that can affect air quality. Thermal comfort requirements are not included in this standard." (ASHRAE 62.1-2004)

Note that although ASHRAE Standard 62.1-2004 will be the relevant standard for the vast majority of LEED-NC projects, certain low-rise residential projects pursuing LEED-NC certification may use ASHRAE Standard 62.2-2004 Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings to comply with this prerequisite.

## Approach and Implementation

Building mechanical and passive ventilation systems seek to ensure that adequate fresh air is available for occupants in the space. Under-ventilated buildings may be stuffy, odorous, uncomfortable and/or unhealthy for occupants. ASHRAE Standard 62.1-2004 establishes minimum requirements for the ventilation air rates in various types of occupied zones and building ventilation systems. The standard takes into account the density of people within an area, the type of activity that is expected to occur in the space, and the nature of the ventilation air delivery system.

## Strategies

There are three basic methods for ventilating buildings:

- ❑ Active Ventilation (i.e., mechanical ventilation)
- ❑ Passive Ventilation (i.e., natural ventilation)
- ❑ Mixed-mode Ventilation (i.e., both mechanical and natural ventilation)

### Mechanically Ventilated Spaces—Ventilation Rate Procedure

For mechanical ventilation systems, ASHRAE Standard 62.1-2004, Section 6, presents procedures for determining the minimum required ventilation rates for various applications, using either the Ventilation Rate Procedure or the Indoor Air Quality Procedure. The Ventilation Rate Procedure is more straightforward to apply and much more common in practice and is the prescribed approach required by EQ Prerequisite 1.

The Ventilation Rate Procedure methodology is found in Section 6.2 of ASHRAE 62.1-2004. The breathing zone outdoor airflow is equal to the sum of the outdoor airflow rate required per person times the zone population, plus the outdoor airflow rate required per unit area times the zone floor area. The standard's Table 6-1 "Minimum Ventilation Rates in Breathing Zone" provides information by occupancy category to determine both the amount of outdoor air needed to ventilate people-related source contaminants and area-related source contaminants. The people-related sources portion of the outdoor air rate addresses actual occupancy density and activity. The area-related sources portion accounts for background off-gassing from building materials, furniture and materials typically found in that particular occupancy. Finally, the required zone outdoor airflow is the breathing zone outdoor airflow adjusted to reflect the "zone air distribution effectiveness" using adjustment factors in Table 6-2 of the standard. For multiple-zone systems, outdoor air intake flow is adjusted to reflect the "system ventilation efficiency" of the air distribution configuration, using adjustment factors in Table 6-3 of the standard.

This prerequisite requires that applicants demonstrate that the delivered minimum zone outdoor airflow for each zone and the outdoor air intake flow for the system meets or exceeds that required by ASHRAE Standard 62.1-2004 for each zone.

### Naturally Ventilated Spaces

ASHRAE Standard 62.1-2004 Section 5.1 provides requirements on the location and size of ventilation openings for naturally ventilated buildings. The standard requires that all naturally ventilated spaces shall be permanently open to and within 25 feet of operable wall or roof openings and that the openable area be at least 4% of the net occupiable floor area. As appropriate, all other non-ventilation-related requirements (i.e., exhaust for combustion appliances, outdoor air assessment, and outdoor air intakes) in the standard must be met to comply with this prerequisite.

### Mixed-Mode Ventilated Spaces

For mixed-mode ventilated spaces, project teams need to meet the minimum ventilation rates required by Chapter 6 of ASHRAE 62.1-2004 regardless of ventilation mode (natural ventilation, mechanical ventilation or both mechanical and natural ventilation).

## Calculations

## Exemplary Performance

This prerequisite is not eligible for exemplary performance under the **Innovation in Design** section.

**Table 1:** Sample Summary Calculations Used to Determine Outdoor Air Ventilation Rates – Mechanically Ventilated

| Zone Identification | | | Standard Case: ASHRAE Std 62.1-2004 Verification Rate Procedure | | | | | | | | | Design Case | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Zone | Occupancy Category | Area (sf) | People Outdoor Air Rate (cfm/person) | Area Outdoor Air Rate (cfm/sf) | Occupant Density (#/1000 sf) | Breathing Zone Outdoor Air Flow Vbz/(CFM) | Table 6-2 Zone Air Distribution Effectiveness Ez | Zone Outdoor Air Flow Voz/(CFM) | Table 6-3 System Ventilation Efficiency Ev | Outdoor Air Intake Flow Vot/(CFM) | Outdoor Air Intake Flow (CFM) | Zone Primary Air Flow Fraction Vpz/(CFM) | Primary Outdoor Air Fraction Zp = Voz/Vpz | Meets Standard? |
| General Office | Office Space | 8000 | 5 | 0.06 | 5 | 680 | 1.0 | 680 | 1.0 | 680 | 800 | 8000 | 0.09 | Y |
| Training Room | Lecture Classroom | 750 | 7.5 | 0.06 | 65 | 411 | 1.2 | 342 | 0.9 | 360 | 400 | 1400 | 0.24 | Y |
| Break Room | Conference Meeting | 250 | 5 | 0.06 | 50 | 63 | 1.0 | 63 | 1.0 | 63 | 75 | 500 | 0.13 | Y |
| **Total** | | **9000** | | | | **1154** | | **1085** | | **1123** | **1275** | **9900** | | **Y** |

*Notes: For the general office space air distrubution is overhead, hence Ez = 1. Outdoor air fraction, Zp, < 0.15, hence System Ventilation Efficiency is 1.0.*
*For the training room, air distrubution is underfloor, hence Ez = 1.2. Outdoor air fraction, Zp < 0.25, hence System Ventilation Efficiency is 0.9.*
*For the break room, air distrubution is overhead, hence Ez = 1. Outdoor air fraction, Zp, < 0.15, hence System Ventilation Efficiency is 1.0.*

**Table 2:** Sample Summary Calculations Used to Determine Outdoor Air Ventilation Rates – Naturally Ventilated

| Zone Identification | ASHRAE Std 62.1-2004 Section 5.1 Natural Ventilation | | | | | |
|---|---|---|---|---|---|---|
| **Zone** | **Net Occupiable Area (sf)** | **Description of Operable Openings** | **Operable Area (sf)** | **Operable Area/ Occupiable Area (%)** | **Ratio > 4%?** | **Operable Openings within 25'?** |
| Bedroom 1 | 150 | (1) 5'x5' slider window | 12.5 | 8.3% | Y | Y |
| Bedroom 2 | 180 | (1) 5' x 5' slider window | 12.5 | 6.9% | Y | Y |
| Living Room | 275 | (1) 6' x 5' slider window & (2) 3' x 1' transome windows | 21 | 7.6% | Y | Y |
| Total | 605 | | 46 | 8% | Y | Y |

## Submittal Documentation

This prerequisite is submitted as part of the **Design Submittal**.

The following project data and calculation information is required to document prerequisite compliance using the v2.2 Submittal Templates:

❑ Design narrative describing the project's ventilation design. Include specific information regarding fresh air intake volumes and any special conditions that affected the project's ventilation design.

AND

❑ For Mechanically Ventilated Buildings: confirmation that the project has been designed to meet the minimum requirements of ASHRAE Standard 62.1-2004, Ventilation for Acceptable Indoor Air Quality, using the Ventilation Rate Procedure.

OR

❑ For Naturally Ventilated Buildings: confirmation that the project has been designed to comply with the requirements for location and size of window openings per ASHRAE Standard 62.1-2004, Section 5.1.

AND

❑ For Naturally Ventilated Buildings: provide applicable project drawings to show the naturally ventilated building zones and the operable window areas.

## Considerations

Good indoor air quality in buildings may yield improved occupant comfort, well-being and productivity. A key component of maintaining indoor air quality in a green building is providing adequate ventilation. ASHRAE Standard 62.1-2004 describes procedures for avoiding the introduction of contaminants; the criterion includes location of air intakes as they relate to potential outdoor sources of contamination. The standard also outlines general ventilation rates for a variety of building types and occupancy categories.

Because ASHRAE Standard 62.1-2004 has become standard ventilation design practice for many areas, generally no additional design effort or capital cost will be required to meet this prerequisite. Its successful implementation reduces potential liability regarding indoor air quality issues for architects, builders, owners, building operators and occupants.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)**

www.ashrae.org

(404) 636-8400

Advances the science of heating, ventilation, air conditioning and refrigeration for the public's benefit through research, standards writing, continuing education and publications.

**U.S. Environmental Protection Agency's Indoor Air Quality Website**

www.epa.gov/iaq

(800) 438-4318

Includes a wide variety of tools, publications and links to address IAQ concerns in schools and large buildings.

## Definitions

**Indoor Air Quality** is the nature of air inside the space that affects the health and well-being of building occupants.

**Mechanical Ventilation** is provided by mechanical powered equipment, such as motor-driven fans and blowers, but not by devices such as wind-driven turbine ventilators and mechanically operated windows. (ASHRAE 62.1-2004)

**Natural Ventilation** is provided by thermal, wind or diffusion effects through doors, windows or other intentional openings in the building. (ASHRAE 62.1-2004)

**Ventilation** is the process of supplying and removing air to and from a space for the purpose of controlling air contaminant levels, humidity or temperature within the space.

**Mixed-mode Ventilation** is a ventilation strategy that combines natural ventilation with mechanical ventilation allowing the building to be ventilated either mechanically or naturally and at times both mechanically and naturally simultaneously.

Required

# Environmental Tobacco Smoke (ETS) Control

## Intent

Minimize exposure of building occupants, indoor surfaces, and ventilation air distribution systems to Environmental Tobacco Smoke (ETS).

## Requirements

OPTION 1

- ❑ Prohibit smoking in the building.
- ❑ Locate any exterior designated smoking areas at least 25 feet away from entries, outdoor air intakes and operable windows.

OR

OPTION 2

- ❑ Prohibit smoking in the building except in designated smoking areas.
- ❑ Locate any exterior designated smoking areas at least 25 feet away from entries, outdoor air intakes and operable windows.
- ❑ Locate designated smoking rooms to effectively contain, capture and remove ETS from the building. At a minimum, the smoking room must be directly exhausted to the outdoors with no re-circulation of ETS-containing air to the non-smoking area of the building, and enclosed with impermeable deck-to-deck partitions. With the doors to the smoking room closed, operate exhaust sufficient to create a negative pressure with respect to the adjacent spaces of at least an average of 5 Pa (0.02 inches of water gauge) and with a minimum of 1 Pa (0.004 inches of water gauge).
- ❑ Performance of the smoking room differential air pressures shall be verified by conducting 15 minutes of measurement, with a minimum of one measurement every 10 seconds, of the differential pressure in the smoking room with respect to each adjacent area and in each adjacent vertical chase with the doors to the smoking room closed. The testing will be conducted with each space configured for worst case conditions of transport of air from the smoking rooms to adjacent spaces with the smoking rooms' doors closed to the adjacent spaces.

OR

OPTION 3 (For residential buildings only)

- ❑ Prohibit smoking in all common areas of the building.
- ❑ Locate any exterior designated smoking areas at least 25 feet away from entries, outdoor air intakes and operable windows opening to common areas.
- ❑ Minimize uncontrolled pathways for ETS transfer between individual residential units by sealing penetrations in walls, ceilings and floors in the residential units, and by sealing vertical chases adjacent to the units.
- ❑ All doors in the residential units leading to common hallways shall be weather-stripped to minimize air leakage into the hallway.

- ❑ If the common hallways are pressurized with respect to the residential units then doors in the residential units leading to the common hallways need not be weather-stripped provided that the positive differential pressure is demonstrated as in Option 2 above, considering the residential unit as the smoking room. Acceptable sealing of residential units shall be demonstrated by a blower door test conducted in accordance with ANSI/ASTM-E779-03, Standard Test Method for Determining Air Leakage Rate By Fan Pressurization, AND use the progressive sampling methodology defined in Chapter 4 (Compliance Through Quality Construction) of the Residential Manual for Compliance with California's 2001 Energy Efficiency Standards (www.energy.ca.gov/title24/residential_manual). Residential units must demonstrate less than 1.25 square inches leakage area per 100 square feet of enclosure area (i.e., sum of all wall, ceiling and floor areas).

### Potential Technologies & Strategies

Prohibit smoking in commercial buildings or effectively control the ventilation air in smoking rooms. For residential buildings, prohibit smoking in common areas, design building envelope and systems to minimize ETS transfer among dwelling units.

## Summary of Referenced Standards

**ANSI/ASTM-E779-03, Standard Test Method for Determining Air Leakage Rate By Fan Pressurization**

To purchase this standard go to: www.astm.org

"1.1 This test method covers a standardized technique for measuring air-leakage rates through a building envelope under controlled pressurization and de-pressurization…1.3 This test method is intended to produce a measure of airtightness of a building envelope..." (ASTM-E779-03)

**Residential Manual for Compliance with California's 2001 Energy Efficiency Standards (For Low Rise Residential Buildings), Chapter 4**

www.energy.ca.gov/title24/residential_manual/res_manual_chapter4.PDF

"The *Standards* require quality design and construction of HVAC systems and air distribution systems. They also offer compliance credit for the construction of less leaky building envelopes. With the 2001 *Standards*, testing of ducts, refrigerant charge, and airflow was added to the prescriptive requirements (Package D) and is assumed as part of the standard design in performance calculations. Many of the compliance credit options require installer diagnostic testing and certification, and independent diagnostic testing and field verification by a certified Home Energy Rater. (Residential Manual for Compliance with California's 2001 Energy Efficiency Standards [For Low Rise Residential Buildings] Chapter 4)

## Approach and Implementation

Prohibit smoking in the building. Provide designated smoking areas outside of the building in locations where ETS will not enter the building or ventilation system. These designated areas should also be located away from concentrations of building occupants or pedestrian traffic. Post information regarding the building's non-smoking policy for all occupants to read.

If interior smoking areas are designed within the building, separate ventilation systems must be installed, and their effectiveness must be tested to ensure that they are isolated from other, non-smoking portions of the building.

The design criteria and instructions for Options 2 and 3 are detailed in the credit requirements and the referenced standard for Option 3.

## Calculations

There are no calculations associated with this credit.

## Exemplary Performance

This prerequisite is not eligible for exemplary performance under the Innovation in Design section.

## Submittal Documentation

This prerequisite is submitted as part of the **Design Submittal**.

The following project data and information is required to document prerequisite compliance using the v2.2 Submittal Templates:

- ❑ Confirmation that the project has met the requirements for the appropriate project category: Non-Smoking Building; Building with Designated Smoking Rooms; or Residential Project.
- ❑ For buildings with interior smoking rooms or for residential projects, provide appropriate copies of construction drawings to document the location of the smoking rooms, designed area separations, and dedicated ventilation systems.
- ❑ An optional narrative may be provided to further describe the testing proto-

cols/results and compliance methods implemented by the project.

## Considerations

The relationship between smoking and various health risks, including lung disease, cancer and heart disease, has been well documented. A strong link between Environmental Tobacco Smoke (ETS) or "secondhand smoke" and health risks has also been demonstrated.

The most effective way to avoid health problems associated with ETS is to prohibit smoking indoors. If this cannot be accomplished, indoor smoking areas should be isolated from non-smoking areas and have separate ventilation systems to avoid the introduction of tobacco smoke contaminants to non-smoking areas.

### Environmental Issues

Separate smoking areas occupy space in the building and may result in a larger building, additional material use and increased energy for ventilation. However, these environmental impacts can be offset by building occupants who are more comfortable, have higher productivity rates, and have lower absenteeism and illnesses.

### Economic Issues

Separate smoking areas add to the design and construction costs of most projects. Maintenance of designated smoking areas also adds to lease and operating costs. Prohibition of indoor smoking can increase the useful life of interior fixtures and furnishings. Smoking within a building contaminates indoor air and can cause occupant reactions ranging from irritation and illness to decreased productivity. These problems increase expenses and liability for building owners, tenants, operators and insurance companies.

### Community Issues

Air is a community natural resource, and promoting clean air benefits everyone. Strict no-smoking policies improve the health of the community as a whole, resulting in lower health care and insurance costs.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**ANSI/ASTM-E779-03, Standard Test Method for Determining Air Leakage Rate By Fan Pressurization**

www.astm.org

Standard may be purchased at this website.

**Energy Rating Systems (HERS) Required Verification And Diagnostic Testing, California Low Rise Residential Alternative Calculation Method Approval Manual**

www.energy.ca.gov/title24/residential_manual/res_manual_chapter4.PDF

**What You Can Do About Secondhand Smoke as Parents, Decision Makers, and Building Occupants**

**U.S. Environmental Protection Agency**

www.epa.gov/smokefree/pubs/etsbro.html

(800) 438-4318

An EPA document on the effects of ETS and measures to reduce human exposure to it.

**Setting the Record Straight: Secondhand Smoke Is a Preventable Health Risk**

**U.S. Environmental Protection Agency**

www.epa.gov/smokefree/pubs/strsfs.html

An EPA document with a discussion of laboratory research on ETS and federal legislation aimed at curbing ETS problems.

### Print Media

*The Chemistry of Environmental Tobacco Smoke: Composition and Measurement*, Second Edition by R.A. Jenkins, B.A. Tomkins, et al., CRC Press & Lewis Publishers, 2000.

*The Smoke-Free Guide: How to Eliminate Tobacco Smoke from Your Environment* by Arlene Galloway, Gordon Soules Book Publishers, 1988.

## Definitions

**Environmental Tobacco Smoke (ETS)**, or secondhand smoke, consists of airborne particles emitted from the burning end of cigarettes, pipes, and cigars, and exhaled by smokers. These particles contain about 4,000 different compounds, up to 40 of which are known to cause cancer.

SS | WE | EA | MR | EQ | ID

Prerequisite 2

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|
| Credit 1 | | | | | |

1 point

EB

# Outdoor Air Delivery Monitoring

## Intent

Provide capacity for ventilation system monitoring to help sustain occupant comfort and well-being.

## Requirements

Install permanent monitoring systems that provide feedback on ventilation system performance to ensure that ventilation systems maintain design minimum ventilation requirements. Configure all monitoring equipment to generate an alarm when the conditions vary by 10% or more from setpoint, via either a building automation system alarm to the building operator or via a visual or audible alert to the building occupants.

FOR MECHANICALLY VENTILATED SPACES

- ❑ Monitor carbon dioxide concentrations within all densely occupied spaces (those with a design occupant density greater than or equal to 25 people per 1000 sq.ft.). $CO_2$ monitoring locations shall be between 3 feet and 6 feet above the floor.
- ❑ For each mechanical ventilation system serving non-densely occupied spaces, provide a direct outdoor airflow measurement device capable of measuring the minimum outdoor airflow rate with an accuracy of plus or minus 15% of the design minimum outdoor air rate, as defined by ASHRAE 62.1-2004.

FOR NATURALLY VENTILATED SPACES

Monitor $CO_2$ concentrations within all naturally ventilated spaces. $CO_2$ monitoring shall be located within the room between 3 feet and 6 feet above the floor. One $CO_2$ sensor may be used to represent multiple spaces if the natural ventilation design uses passive stack(s) or other means to induce airflow through those spaces equally and simultaneously without intervention by building occupants.

## Potential Technologies & Strategies

Install carbon dioxide and airflow measurement equipment and feed the information to the HVAC system and/or Building Automation System (BAS) to trigger corrective action, if applicable. If such automatic controls are not feasible with the building systems, use the measurement equipment to trigger alarms that inform building operators or occupants of a possible deficiency in outdoor air delivery.

## Summary of Referenced Standard

There is no standard referenced for this credit.

## Approach and Implementation

Building HVAC systems are designed to flush out indoor airborne contaminants by exhausting old air and replacing it with fresh outdoor air. The rate of ventilation air exchange is generally determined in the design phase based on space density and type of occupancy. Many conventional ventilation systems do not directly measure the amount of outdoor air delivered. Implementation of the following strategies is recommended to achieve this credit.

### Outdoor Air Flow Monitoring

Air flow monitoring of the outdoor air rate validates that the HVAC equipment is delivering the required ventilation rate. Air balance control methodologies, such as fan tracking and measuring building-pressurization based strategies, do not directly determine that appropriate ventilation air is being provided and do not satisfy the credit requirement. The ventilation rate can be measured at the outdoor air intake to an air distribution system using a variety of airflow devices including Pitot tubes, Venturi meters and rotating vane anemometers. Ventilation rate for a particular HVAC system can also be accurately determined from a mass balance calculation if both supply air flow and return air flow are directly measured with air flow monitoring devices. To satisfy the requirements of this credit, the measurement devices must detect when the system is 15% below the design minimum outdoor air rate. When the ventilation system fails to provide the required levels of fresh air, the monitoring system should be configured to deliver a visible or audible alert to the system operator. This alert will indicate to the system operator that operational adjustments may be necessary.

The minimum outdoor air rate may change based on the design and modes of the HVAC system. Constant volume systems, with steady-state design occupancy conditions usually have different outdoor air rates for weekdays and night-time or off-peak conditions. In variable air volume (VAV) systems, the rate of outdoor air needs to stay above the design minimum even when the supply air flow is reduced due to reduced thermal load conditions.

### $CO_2$ Monitoring

The effectiveness of the ventilation system to deliver the needed outdoor air can also be monitored using carbon dioxide ($CO_2$) monitors. In demand controlled ventilation (DCV) systems, where the outdoor air rate supplied to an area is based on readings taken by one or more $CO_2$ monitors located within the occupied spaces, the system-wide outdoor air rate will fluctuate. A DCV system, is a typical energy conservation strategy for large spaces with variable occupancy, such as a large lecture hall where the number of people and times of use varies significantly. In this type of operation, the monitoring system confirms that the space—the lecture hall—is receiving adequate outdoor air for the current occupancy, and that the central system adjusts the ventilation rate to match the changing requirement.

$CO_2$ sensors, when properly placed, are a practical means of confirming that a ventilation system is functioning properly. There are two typical system configurations that generally meet the requirements of this credit.

One approach utilizes $CO_2$ sensors that use measured concentration to provide an alert. An indoor concentration of 1000 ppm has commonly been used in the past as the setpoint for the alarm, but a higher alarm concentration may be appropriate when the design complies with Standard 62.1-2004, since the effective ventilation rate per person has been reduced significantly for some zones. ASHRAE 62.1-2004 Users Manual Appendix A provides a further discussion on $CO_2$ sensors including demand control ventilation.

$CO_2$ monitoring locations should be selected so that they provide representative readings of the $CO_2$ concentrations in occupied spaces. Providing multiple $CO_2$ monitoring stations throughout occupied spaces will provide better information and control than providing a single $CO_2$ monitor for the entire system. A single $CO_2$ monitor, typically installed in the return air duct, is less expensive and more straightforward to implement than proving multiple sensors, but may not yield information that identifies areas within the building that are under-ventilated.

### $CO_2$ Monitoring in Densely Occupied Spaces

Within buildings that are mechanically ventilated, the $CO_2$ level within each densely occupied space needs to be monitored to satisfy the credit requirements. The density factor is 25 people per 1000 sq.ft. or 40 sq.ft. per person; for example, a 240 sq.ft. conference room planned for 6 or more people would need to be monitored. $CO_2$ monitors in densely occupied spaces should be mounted in the space within the vertical breathing zone—between 3 and 6 feet above the floor.

### Ventilation Air Flow Monitoring in Non-Densely Occupied Spaces

For mechanically-ventilated spaces with occupant density less than 25 people per 1000 sq.ft., this LEED-NC credit requires that the outdoor ventilation rate be directly measured and compared against the minimum required ventilation rate. Typically this will be provided by air flow monitoring stations located in the outdoor air intakes of each central HVAC air distribution system. The direct outdoor airflow measurement device must be capable of measuring the outdoor airflow rate at all expected system operating conditions within an accuracy of plus or minus 15% of the design minimum outdoor air rate.

### $CO_2$ Monitoring in Naturally Ventilated Spaces

For naturally ventilated buildings, monitoring $CO_2$ levels in the occupied space provides feedback to building occupants and operators, so that they can make operational adjustments, such as opening windows, if the space becomes under ventilated. The $CO_2$ monitors in naturally ventilated spaces should be mounted in the vertical breathing zone between 3 and 6 feet above the floor.

### Operations & Maintenance

As part of the system commissioning, project teams should confirm that the outdoor air delivery monitoring system is calibrated, and that the appropriate setpoints and control sequences have been implemented. Provide the building owner, maintenance personnel and occupants with the information needed to understand, maintain and respond to the monitoring system. Maintenance personnel should make inspection of $CO_2$ monitors and airflow monitoring stations part of routine O&M and preventive maintenance activities. Sensors should be recalibrated based on the manufacturer's requirements. It is recommended to use $CO_2$ sensors that require recalibration no less than every 5 years. If a $CO_2$ monitor is allowed to fall out of calibration it may indicate that indoor $CO_2$ concentrations are lower or higher than they actually are, leading to under- or over-ventilation of the space.

A permanent ventilation monitoring system assists in detecting indoor air quality problems quickly so that corrective action can be taken. Under-ventilation of a space can lead to unsatisfactory indoor environmental conditions and occupant discomfort. Over-ventilation of a space may needlessly increase HVAC energy costs.

### Building Type

Air flow and $CO_2$ monitoring systems can be applied to any building or HVAC system type—including both mechanically and naturally ventilated buildings. In addition to ventilation alarms, such monitors can provide building operators and automated control systems (i.e., demand control ventilation) with information that allows for operational adjustments, such as increasing or decreasing intake airflow rates.

For naturally ventilated buildings and spaces served by HVAC systems that do not allow for active control of ventilation rates, $CO_2$ monitors in the occupied spaces can provide building occupants and operators with useful information that allows for operational adjustments, such as opening windows or adjusting fixed ventilation rates, if the $CO_2$ monitors indicate that the space is under ventilated.

## Calculations

There are no calculations required for this credit.

## Exemplary Performance

This credit is not eligible for exemplary performance under the Innovation in Design section.

## Submittal Documentation

This prerequisite is submitted as part of the **Design Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

- ❑ Confirmation of the type of ventilation system and installed controls.
- ❑ Design narrative describing the project's ventilation design and $CO_2$ monitoring system. Include specific information regarding location and quantity of installed monitors, operational parameters and setpoints.
- ❑ Provide copies of the applicable project drawings to document the location and type of installed sensors. Drawings should also show natural ventilation components (operable windows, air intakes, etc.) as applicable.

## Considerations

### Cost Issues

$CO_2$ and ventilation rate monitoring systems increase initial construction costs compared to ventilation systems without such monitoring capabilities. Capital costs and annual costs for air flow monitoring equipment maintenance and calibration procedures may be offset by reduced absenteeism, increased occupant productivity and/or reduced HVAC energy use.

### Regional Issues

Ambient outdoor $CO_2$ concentrations may fluctuate somewhat based on local and regional factors, between approximately 300 and 500 ppm. The time-of-day fluctuations near major congested highways and annual fluctuations, if any, should also be considered. High ambient $CO_2$ concentrations are typically an indicator of combustion or other contaminant sources. Lower ventilation rates may yield a sense of stuffiness or general dissatisfaction with IAQ.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**ASHRAE 62.1-2004 Users Manual** Appendix A

www.ashrae.org

Provides information on $CO_2$ sensors including demand control ventilation.

**American Society of Heating, Refrigerating and Air-Conditioning Engineers**

**(ASHRAE)**

www.ashrae.org

(404) 636-8400

Advances the science of heating, ventilation, air conditioning and refrigeration for the public's benefit through research, standards writing, continuing education and publications.

**Building Air Quality: A Guide for Building Owners and Facility Managers**

www.epa.gov/iaq/largebldgs/baqtoc.html

(800) 438-4318

An EPA publication on IAQ sources in buildings and methods to prevent and resolve IAQ problems.

### Print Media

*Air Handling Systems Design* by Tseng-Yao Sun, McGraw Hill, 1992.

ASHRAE Standard 55-2004: Thermal Environmental Conditions for Human Occupancy, ASHRAE, 2004

ASHRAE Standard 62.1-2004: Ventilation for Acceptable Indoor Air Quality, ASHRAE, 2004

ASHRAE Standard 62.2-2004: Ventilation for Acceptable Indoor Air Quality in Low-Rise Residential Buildings, ASHRAE, 2004

ASTM D 6245-1998: Standard Guide for Using Indoor Carbon Dioxide Concentrations to Valuate Indoor Air Quality and Ventilation, ASTM, 1998

*Efficient Building Design Series, Volume 2: Heating, Ventilating, and Air Conditioning* by J. Trost and Frederick Trost, Prentice Hall, 1998.

## Definitions

**$CO_2$** is carbon dioxide.

**Mechanical Ventilation** is ventilation provided by mechanically powered equipment, such as motor-driven fans and blowers, but not by devices such as wind-driven turbine ventilators and mechanically operated windows. (ASHRAE 62.1-2004)

**Natural Ventilation** is ventilation provided by thermal, wind, or diffusion effects through doors, windows, or other intentional openings in the building. (ASHRAE 62.1-2004)

**ppm** stands for parts per million

**Ventilation** is the process of supplying air to or removing air from a space for the purpose of controlling air contaminant levels, humidity, or temperature within the space. (ASHRAE 62.1-2004)

# Increased Ventilation

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|

Credit 2

1 point

## Intent

Provide additional outdoor air ventilation to improve indoor air quality for improved occupant comfort, well-being and productivity.

## Requirements

FOR MECHANICALLY VENTILATED SPACES

- ❑ Increase breathing zone outdoor air ventilation rates to all occupied spaces by at least 30% above the minimum rates required by ASHRAE Standard 62.1-2004 as determined by EQ Prerequisite 1.

FOR NATURALLY VENTILATED SPACES

- ❑ Design natural ventilation systems for occupied spaces to meet the recommendations set forth in the Carbon Trust Good Practice Guide 237 [1998]. Determine that natural ventilation is an effective strategy for the project by following the flow diagram process shown in Figure 1.18 of the Chartered Institution of Building Services Engineers (CIBSE) Applications Manual 10: 2005, Natural ventilation in non-domestic buildings.

AND

- ❑ Use diagrams and calculations to show that the design of the natural ventilation systems meets the recommendations set forth in the CIBSE Applications Manual 10: 2005, Natural ventilation in non-domestic buildings.

OR

- ❑ Use a macroscopic, multi-zone, analytic model to predict that room-by-room airflows will effectively naturally ventilate, defined as providing the minimum ventilation rates required by ASHRAE 62.1-2004 Chapter 6, for at least 90% of occupied spaces.

## Potential Technologies & Strategies

For mechanically ventilated spaces: use heat recovery, where appropriate, to minimize the additional energy consumption associated with higher ventilation rates.

For naturally ventilated spaces: follow the eight design steps described in the Carbon Trust Good Practice Guide 237: 1) Develop design requirements, 2) Plan airflow paths, 3) Identify building uses and features that might require special attention, 4) Determine ventilation requirements, 5) Estimate external driving pressures, 6) Select types of ventilation devices, 7) Size ventilation devices, 8) Analyze the design. Use public domain software such as NIST's CONTAM, Multizone Modeling Software, along with LoopDA, Natural Ventilation Sizing Tool, to analytically predict room-by-room airflows.

## Summary of Referenced Standards

**ASHRAE Standard 62.1-2004: Ventilation For Acceptable Indoor Air Quality**

American Society of Heating, Refrigerating and Air-Conditioning Engineers

www.ashrae.org

(800) 527-4723

"The purpose of this standard is to specify minimum ventilation rates and indoor air quality that will be acceptable to human occupants and are intended to minimize the potential for adverse health effects. This standard is intended for regulatory application to new buildings, additions to existing buildings, and those changes to existing buildings that are identified in the body of the standard. This standard applies to all indoor or enclosed spaces that people may occupy, except where other applicable standards and requirements dictate larger amounts of ventilation than this standard. Release of moisture in residential kitchens and bathrooms, locker rooms, and swimming pools is included in the scope of this standard. Additional requirements for laboratory, industrial, and other spaces may be dictated by workplace and other standards, as well as by the processes occurring within the space. This standard considers chemical, physical, and biological contaminants that can affect air quality. Thermal comfort requirements are not included in this standard." (ASHRAE 62.1-2004)

Note that although ASHARE Standard 62.1-2004 will be the relevant standard for the vast majority of LEED-NC projects, certain low-rise residential projects pursuing LEED-NC certification may use ASHRAE Standard 62.2-2004 Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings to comply with this credit.

**The Carbon Trust Good Practice Guide 237—Natural ventilation in non-domestic buildings—a guide for designers; developers and owners** (1998)

www.thecarbontrust.org.uk/energy/pages/publication_view.asp?PubID=4603

"Carefully designed, naturally ventilated buildings can be cheaper to construct, maintain and operate than more heavily serviced equivalents. Occupants generally prefer windows that can be opened, and natural light, both of which are features of well designed, naturally ventilated buildings. The Guide summarizes the benefits of natural ventilation and considers the commercial implications, illustrating the issues by means of case studies." (The Carbon Trust)

**CIBSE Applications Manual 10: 2005, Natural ventilation in non-domestic buildings**

www.cibse.org

"This publication is a major revision of the Applications Manual (AM) first published in 1997. At that time, there was a significant expansion of interest in the application of engineered natural ventilation to the design of non-domestic buildings. The original AM10 sought to capture the state of knowledge as it existed in the mid-90s and present it in a form suited to the needs of every member of the design team. Some 10 years on from the time when the initial manual was conceived, the state of knowledge has increased, and experience in the design and operation of naturally ventilated buildings has grown. This revision of AM10 is therefore a timely opportunity to update and enhance the guidance offered to designers and users of naturally ventilated buildings." (CIBSE)

## Approach and Implementation

A green building should provide its occupants with superior indoor air quality to support their health, comfort and well-being. A key component for maintaining superior indoor air quality is providing adequate ventilation rates. Under-ventilated buildings may be stuffy, odorous, uncomfortable and/or unhealthy for occupants.

Building ventilation systems, including both active HVAC systems and natural ventilation systems, are designed and installed to introduce fresh outside air into the building while exhausting an equal amount of building air. HVAC systems typically serve other functions as well, including providing thermal comfort for occupants. Building conditioning systems that provide enhanced ventilation air, as efficiently and effectively as possible, will help to maintain a high standard of indoor air quality in the building.

The requirement for this credit is a 30% increase in ventilation rates beyond the amounts required by ASHRAE 62.1-2004 in office buildings at the breathing zone. The ASHRAE 62.1-2004 rates are approximately 15% to 20% lower than the ASHRAE 62.1-2001 rates. The threshold for this credit was developed based on documented research demonstrating indoor air quality benefits from ventilation rates in the 25 cfm/person range. To achieve 25 cfm/person, the increase would be closer to 50%. 30% was chosen as a compromise between indoor air quality and energy efficiency.

### Planning & Design Phase

Most projects decide early on whether to have a mechanical ventilation system, a passive ventilation system, or a combination of both. This decision may be influenced by the building size and type, as well as climatic, economic and organizational influences. Figure 1 from CIBSE AM10 provides a decision diagram to aid in making a knowledgeable evaluation. In addition to these considerations, project teams considering natural ventilation should evaluate site conditions and building design. Potential IAQ problems might result from heavy traffic, nearby polluting industries and neighboring waste management sites.

For mechanical ventilation, the design and operating setpoints of the HVAC system will be the primary influence on ventilation rates in the building. Building owners and designers should determine if increasing ventilation rates beyond ASHRAE Standard 62.1-2004 requirements is a good idea for their facility. The HVAC design and sizing should account for increased ventilation rates if this strategy is applied.

Occupants generally take a primary role in managing ventilation conditions in naturally ventilated buildings by opening and closing windows as necessary and appropriate. Naturally ventilated buildings generally have somewhat more variable ventilation rates than actively conditioned buildings, whose systems are often designed to maintain no less than minimum ventilation requirements through all periods of occupancy.

## Strategies

There are three basic methods for ventilating buildings:

- ❑ Active Ventilation (i.e., mechanical ventilation)
- ❑ Passive Ventilation (i.e., natural ventilation)
- ❑ Mixed-mode Ventilation (i.e., both mechanical and natural ventilation)

Projects employing both mechanical and natural ventilation (i.e., mixed-mode ventilation) strategies will need to exceed minimum ventilation rates required by ASHRAE Standard 62.1-2004, Chapter 6 by at least 30%.

### Mechanically Ventilated Spaces—Ventilation Rate Procedure

For mechanical ventilation systems, ASHRAE Standard 62.1-2004, Section

6, outlines procedures for determining ventilation rates for various applications, using either the Ventilation Rate Procedure or the Indoor Air Quality Procedure. The Ventilation Rate Procedure is more straightforward to apply and much more common in practice—and it is the prescribed approach used in EQ Prerequisite 1, Minimum IAQ Performance.

The Ventilation Rate Procedure methodology is found in Section 6.2 of ASHRAE 62.1-2004. The breathing zone outdoor airflow is equal to the sum of the outdoor airflow rate required per person times the zone population, plus the outdoor airflow rate required per unit area times the zone floor area. The standard's Table 6-1 "Minimum Ventilation Rates in Breathing Zone" provides information by occupancy category to determine both the amount of outdoor air needed to ventilate people-related source contaminants and area-related source contaminants. The people-related sources portion of the outdoor air rate addresses actual occupancy density and activity. The area-related sources portion accounts for background off-gassing from building materials, furniture and materials typically found in that particular occupancy. Finally, the required zone outdoor airflow is the breathing zone outdoor airflow adjusted to reflect the "zone air distribution effectiveness" using adjustment factors in Table 6-2 of the Standard. For multiple-zone systems, outdoor air intake flow is adjusted to reflect the "system ventilation efficiency" for the air distribution configuration, using adjustment factors in Table 6-3 of the Standard.

This LEED-NC credit requires that applicants demonstrate that the delivered minimum zone outdoor airflow is at least 30% higher than is the minimum airflow required by ASHRAE Standard 62.1-2004 for each zone. **Table 1** shows how the sample space used in EQ Prerequisite 1 has attained the 30% increase.

### Naturally Ventilated Spaces

Project teams electing natural ventilation have two primary means of demonstrating credit compliance:

- ❑ The compliance path found in Chapter 2 of The CIBSE Applications Manual 10 (AM10)

OR

- ❑ Documentation using a macroscopic, multi-zone, analytic model that predicts room-by-room outdoor air flow rates.

Those using the CIBSE AM10 (see **Figure 1**) begin by establishing the required flow rates through each space. There is an acceptable average rate needed for IAQ and thermal comfort; increasing this

**Table 1:** ASHRAE Std 62.1-2004 Ventilation Rate Procedure

| Zone Identification | | | Standard Case: ASHRAE Std 62.1-2004 Verification Rate Procedure | | | | | | | | | Design Case | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Zone | Occupancy Category | Area (sf) | People Outdoor Air Rate (cfm/ person) | Table 6-1 Area Outdoor Air Rate (cfm/ sf) | Occupant Density (#/ 1000 sf) | Breathing Zone Outdoor Air Flow Vbz (CFM) | Table 6-2 Zone Air Distribution Effectiveness Ez | Zone Outdoor Air Flow Voz (CFM) | Table 6-3 System Ventilation Efficiency Ev | Outdoor Air Intake Flow Vot (CFM) | Outdoor Air Intake Flow (CFM) | Zone Primary Air Flow Faction Vpz (CFM) | Primary Outdoor Air Fraction Zp = Voz/ Vpz | % Increase Over Standard |
| General Office | Office Space | 8000 | 5 | 0.06 | 5 | 680 | 1.0 | 680 | 1.0 | 680 | 900 | 8000 | 0.09 | 32% |
| Training Room | Lecture Classroom | 750 | 7.5 | 0.06 | 65 | 411 | 1.2 | 342 | 0.9 | 380 | 500 | 1400 | 0.24 | 32% |
| Break Room | Conference Meeting | 250 | 5 | 0.06 | 50 | 63 | 1.0 | 63 | 1.0 | 63 | 85 | 500 | 0.13 | 36% |
| **Total** | | **9000** | | | | **1154** | | **1085** | | **1123** | **1485** | **9900** | | **32%** |

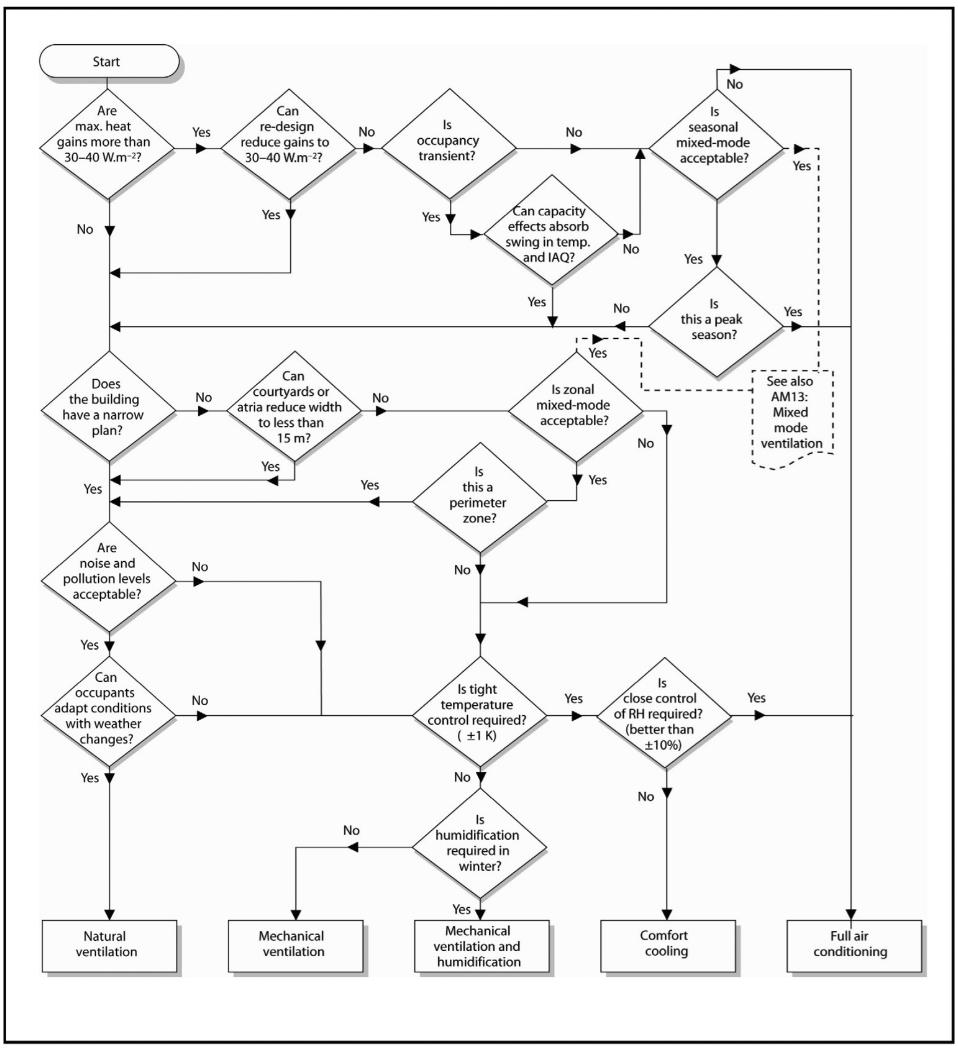
Notes: *For the general office space air distrubution is overhead, hence Ez = 1. Outdoor air fraction, Zp, < 0.15, hence System Ventilation Efficiency is 1.0.*
*For the training room, air distrubution is underfloor, hence Ez = 1.2. Outdoor air fraction, Zp < 0.25, hence System Ventilation Efficiency is 0.9.*
*For the break room, air distrubution is overhead, hence Ez = 1. Outdoor air fraction, Zp, < 0.15, hence System Ventilation Efficiency is 1.0.*

rate results in wasted energy during the heating seasons. There is also additional ventilation needed for the summer cooling requirements.

CIBSE AM10 lists several natural ventilation analysis methods, either using a separate manual or simulation software. Project teams should confirm their choice with justification. Submittals will need to include a narrative that provides information on the building, its orientation and the glazing ratios. Include a summary of the internal heat gains and weather conditions. Explain the ventilation strategy, including the airflow paths, the rates planned for different operational periods during the day and night, the peak internal temperatures, and means of shading for summer solar gains. Provide sample calculations on the determination of opening size for operable windows, trickle vents and louvers. Finally, include the calculations for the driving pressure showing the effects of both wind and stack-induced pressure differentials.

Project teams using a macroscopic, multi-zone, analytic model that predicts room-by-room air flow rates will need to provide a narrative providing the same information listed above. They will also

**Figure 1:** Selecting a Strategy, from CIBSE Applications Manual 10:2005, Natural ventilation in non-domestic buildings




*Reproduced with permission from The Chartered Institute of Building Services Engineers, London* need to demonstrate that 90% of the occupied areas are effectively ventilated, that is to provide minimum ventilation rates required by ASHRAE 62.1-2004, Chapter 6, by natural ventilation and should provide room-by-room outdoor airflow rates predicted by the analysis.

## Calculations

For mechanical ventilation systems, project teams should prepare calculations to demonstrate that the design ventilation rates for each zone are at least 30% above the minimum rates required by the Ventilation Rate Procedure of ASHRAE 62.1-2004. This calculation should take the form of a table or spreadsheet similar to **Table 1**. The same calculation may be used to document both EQ Prerequisite 1 and EQ Credit 2.

If this credit is pursued, the design ventilation rates, at least 30% higher than standard ventilation rates, should be incorporated into the energy calculations EA Credit 1. Depending on the system design and climatic factors, increased ventilation may reduce the calculated and actual energy performance of the building.

For naturally ventilated spaces, project teams should provide sample calculations demonstrating how opening size for operable windows, trickle vents and louvers were determined in accordance with CIBSE AM10 and the Carbon Trust Good Practice Guide 237. See **Figure 1**.

For naturally ventilated spaces, project teams using a macroscopic, multi-zone, analytic model that predicts room-by-room air flow rates will need to provide the room-by-room outdoor airflow rates predicted by the analysis and a comparison to minimum ventilation rates required by ASHRAE Standard 62.1-2004, Chapter 6.

## Exemplary Performance

This credit is not eligible for exemplary performance under the **Innovation in Design** section.

## Submittal Documentation

This credit is submitted as part of the **Design Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

### Mechanically Ventilated Buildings

- ❑ Confirmation that the breathing zone ventilation rates in all occupied spaces have been designed to exceed the minimum rates required by ASHRAE Standard 62.1-2004 or the applicable local code, whichever is more stringent, by a minimum of 30%.
- ❑ Design narrative describing the project's ventilation system design. Include specific information regarding the fresh air intake volume for each specific occupied zone to demonstrate that the design exceeds the referenced standard or the applicable local code, whichever is more stringent, by at least 30%.

### Naturally Ventilated Buildings

- ❑ Confirmation that the natural ventilation system has been designed to meet the recommendations set forth in the Carbon Trust Good Practice Guide 237 [1988].
- ❑ Design narrative describing the design method (CIBSE Method/Analytic Model) utilized in determining the natural ventilation design for the project. Provide specific information regarding calculation methodology and/or model results to demonstrate that the ventilation design complies with the referenced standards.

## Considerations

### Cost Issues

Increasing ventilation rates by 30% beyond ASHRAE Standard 62.1-2004 will yield higher HVAC energy costs and potentially greater HVAC capacity than associated with the ventilation rates established in the standard. This increase in HVAC capacity and energy use will be more pronounced in extreme climates than in mild, temperate climates. Some projects may choose to increase the outdoor air rate, and accept higher HVAC equipment and energy costs, because research indicates that the resulting indoor air quality is associated with improved employee health, welfare, well-being and productivity.

While a naturally ventilated building may have less equipment than a comparable mechanically ventilated building, natural ventilation designs may require additional costs for operable windows, increased thermal mass, and other architectural elements which allow for passive ventilation and space conditioning. Energy and maintenance costs of naturally ventilated buildings tend to be lower than for comparable mechanically ventilated spaces.

### Regional Issues

Additional ventilation is more practical for mild climates, where increasing ventilation rates beyond the ASHRAE 62.1-2004 minimum rates will not have as great an impact on HVAC systems capacity and energy consumption as in hot, humid or cold climates. Natural ventilation and passive conditioning approaches are also more typical in mild and temperate climates, although there are precedents for passively conditioned buildings in all climates. There may be variable conditions in naturally ventilated buildings, but occupants are satisfied because they control their environment.

### Synergies and Trade-Offs

In addition to designing the HVAC systems properly and selecting appropriate building materials, increasing ventilation rates beyond standard practice may be one strategy to provide superior indoor air quality. Managing indoor air quality concerns during construction and operations is also appropriate for many green building projects.

For mechanically ventilated and air-conditioned buildings, increasing ventilation rates will require somewhat larger HVAC system capacity and greater energy use adding to both capital and operational costs. Natural ventilation systems can provide increased ventilation rates, good indoor air quality, and occupant control over thermal comfort and ventilation via operable windows while potentially reducing operating costs compared to mechanical ventilation systems.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**ASHRAE Standard 62.1-2004: Ventilation For Acceptable Indoor Air Quality**

**American Society of Heating, Refrigerating and Air-Conditioning Engineers**

www.ashrae.org

(800) 527-4723

**The Carbon Trust Good Practice Guide 237—Natural ventilation in non-domestic buildings—a guide for designers; developers and owners** (1998)

www.thecarbontrust.org.uk

**CIBSE Applications Manual 10: 2005, Natural ventilation in non-domestic buildings**

www.cibse.org

"This publication is a major revision of the Applications Manual (AM) first published in 1997. At that time, there was a significant expansion of interest in the application of engineered natural ventilation to the design of non-domestic buildings. The original AM10 sought to capture the state of knowledge as it existed in the mid-90s and present it in a form suited to the needs of every member of the design team. Some 10 years on from the time when the initial manual was conceived, the state of knowledge has increased, and experience in the design and operation of naturally ventilated buildings has grown. This revision of AM10 is therefore a timely opportunity to update and enhance the guidance offered to designers and users of naturally ventilated buildings." (CIBSE)

**American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)**

www.ashrae.org

(404) 636-8400

Advances the science of heating, ventilation, air conditioning and refrigeration for the public's benefit through research, standards writing, continuing education and publications. To purchase ASHRAE standards and guidelines, visit the bookstore on the ASHRAE website and search for the desired publication.

**Building Assessment, Survey and Evaluation Study**

**U.S. Environmental Protection Agency**

www.epa.gov/iaq/largebldgs/base_page.htm

**Building Air Quality Action Plan**

**U.S. Environmental Protection Agency**

www.epa.gov/iaq/largebldgs/actionpl.html

**The Chartered Institution of Building Services Engineers (CIBSE)**

www.cibse.org

This organization, located in London, on its own and in collaboration with other entities, publishes a full series of guides on the topic of ventilation, including natural ventilation.

## Definitions

**Air Conditioning** is the process of treating air to meet the requirements of a conditioned space by controlling its temperature, humidity, cleanliness and distribution. (ASHRAE 62.1-2004)

**Breathing Zone** is the region within an occupied space between planes 3 and 6 ft. above the floor and more than 2 ft. from the walls or fixed air-conditioning equipment.

**Conditioned Space** is that part of a building that is heated or cooled, or both, for the comfort of occupants. (ASHRAE 62.1-2004)

**Contaminant** is an unwanted airborne constituent that may reduce acceptability of the air. (ASHRAE 62.1-2004)

**Exfiltration** is uncontrolled outward air leakage from conditioned spaces through unintentional openings in ceiling, floors and walls to unconditioned spaces or the outdoors caused by pressure differences across these openings due to wind, inside-outside temperature differences (stack effect), and imbalances between supply and exhaust airflow rates. (ASHRAE 62.1-2004)

**Exhaust Air** is the air removed from a space and discharged to outside the building by means of mechanical or natural ventilation systems.

**Infiltration** is uncontrolled inward air leakage from conditioned spaces through unintentional openings in ceilings, floors and walls from unconditioned spaces or the outdoors caused by the same pressure differences that induce exfiltration. (ASHRAE 62.1-2004)

**Makeup Air** is any combination of outdoor and transfer air intended to replace exhaust air and exfiltration. (ASHRAE 62.1-2004)

**Mechanical Ventilation** is ventilation provided by mechanically powered equipment, such as motor-driven fans and blowers, but not by devices such as wind-driven turbine ventilators and mechanically operated windows. (ASHRAE 62.1-2004)

**Natural Ventilation** is ventilation provided by thermal, wind, or diffusion effects through doors, windows, or other intentional openings in the building. (ASHRAE 62.1-2004)

**Outdoor Air** is the ambient air that enters a building through a ventilation system, through intentional openings for natural ventilation, or by infiltration. (ASHRAE 62.1-2004)

**Recirculated Air** is the air removed from a space and reused as supply air. (ASHRAE 62.1-2004)

**Return Air** is the air removed from a space to be then recirculated or exhausted. (ASHRAE 62.1-2004)

**Supply Air** is the air delivered by mechanical or natural ventilation to a space, composed of any combination of outdoor air, recirculated air, or transfer air. (ASHRAE 62.1-2004)

## Case Study

**Navy Federal Credit Union, Remote Call Center**

**Pensacola, FL**

Owner: Navy Federal Credit Union

Photo © Maguire Photographics, Courtesy of ASD

The Navy Federal Credit Union's Remote Call Center is a LEED® v2.0 Gold Project that is located on 19 acres of Live Oak forest (only one tree was removed to accommodate the new building). The project achieved all but one credit in the Indoor Environmental Quality section of LEED-NC v2.0, ensuring an optimal environment for the employees of the call center. The project's inclusion of an underfloor air system enhances ventilation effectiveness for 95% of the building occupants, thereby achieving the intent of EQ Credit 2.

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|

Credit 3.1

1 point

# Construction IAQ Management Plan

## During Construction

### Intent

Reduce indoor air quality problems resulting from the construction/renovation process in order to help sustain the comfort and well-being of construction workers and building occupants.

### Requirements

Develop and implement an Indoor Air Quality (IAQ) Management Plan for the construction and pre-occupancy phases of the building as follows:

- ❑ During construction meet or exceed the recommended Control Measures of the Sheet Metal and Air Conditioning Contractors National Association (SMACNA) IAQ Guidelines for Occupied Buildings under Construction, 1995, Chapter 3.
- ❑ Protect stored on-site or installed absorptive materials from moisture damage.
- ❑ If permanently installed air handlers are used during construction, filtration media with a Minimum Efficiency Reporting Value (MERV) of 8 shall be used at each return air grille, as determined by ASHRAE 52.2-1999. Replace all filtration media immediately prior to occupancy.

### Potential Technologies & Strategies

Adopt an IAQ management plan to protect the HVAC system during construction, control pollutant sources and interrupt contamination pathways. Sequence the installation of materials to avoid contamination of absorptive materials such as insulation, carpeting, ceiling tile and gypsum wallboard. Coordinate with EQ Credits 3.2 and 5 to determine the appropriate specifications and schedules for filtration media.

If possible, avoid using permanently installed air handlers for temporary heating/cooling during construction. Consult this LEED-NC v2.2 Reference Guide for more detailed information on how to ensure the well-being of construction workers and building occupants if permanently installed air handlers must be used during construction.

## Summary of Referenced Standards

**IAQ Guidelines for Occupied Buildings Under Construction**

Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)

www.smacna.org

(703) 803-2980

This standard provides an overview of air pollutants associated with construction, control measures, construction process management, quality control, communications with occupants, and case studies. Consult the referenced standard for measures to protect the building HVAC system and maintain acceptable indoor air quality during construction and demolition activities.

**ANSI/ASHRAE 52.2-1999: Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size**

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

www.ashrae.org

(800) 527-4723

This standard presents methods for testing air cleaners for two performance characteristics: the ability of the device to remove particles from the air stream and the device's resistance to airflow. The minimum efficiency reporting value (MERV) is based on three composite average particle size removal efficiency (PSE) points. Consult the standard for a complete explanation of MERV value calculations.

## Approach and Implementation

### Strategies

This credit hinges on performance by the general contractor. The IAQ Management Plan should be completed before construction begins and should include construction-related IAQ procedures in the pre-construction and construction progress meeting agendas. Education of subcontractors and all field personnel on the goals of the IAQ Management Plan and importance of following the plan's procedures ensures compliance and achievement. If warranted, select a member of the contractor's team to serve as the IAQ Manager who will have the responsibility to identify IAQ problems and their mitigation. The referenced SMACNA standard recommends control measures in five areas: HVAC protection, source control, pathway interruption, housekeeping and scheduling. For each project, review the applicability of each control measure and include those that apply in the final IAQ Management Plan. The control measures are as follows:

### HVAC Protection

Ideally, permanently installed HVAC systems should not be used during the construction process as using this equipment can cause contamination of the HVAC system. In most cases, use of the HVAC system during construction activates the manufacturer's warranty, exposing the contractor to potential out-of-pocket costs if problems occur when the manufacturer's warranty has expired but the warranty for the building has not. Using temporary heaters is feasible, practical and generally not costly.

Protect all HVAC equipment from both dust and odors. Ideally, do not use the system during construction, particularly during demolition. Seal all duct and equipment openings with plastic. If the system must be operated to maintain service to other occupied portions of the building or to protect finished work be sure to protect the return/negative pressure side of the system. If the returns cannot be closed off, install and maintain temporary filters over grilles and openings. To comply with the credit requirements the filtration medium must have a rating of MERV 8 or better. If an unducted plenum over the construction zone must be used, isolate it by having all ceiling tiles in place. Leaks in the return ducts and air handlers should be checked. Make needed repairs promptly. Avoid using the mechanical rooms for construction storage.

Replace all filtration media immediately prior to occupancy, installing only a single set of final filtration media. Note that the requirement for MERV 13 rated filters has been moved to EQ Credit 5. This credit does not regulate the efficiency of the filters used for the long-term operation of the building.

### Source Control

Specify finish materials such as paints, carpet, composite wood, adhesives, and sealants that have low toxicity levels, or none at all. The selection of low-emitting materials is covered under EQ Credit 4. The IAQ Management Plan should specify the control measures for materials containing VOCs. Recover, isolate and ventilate containers housing toxic materials. Also, avoid exhaust fumes from idling vehicles and gasoline fueled tools.

### Pathway Interruption

During construction, isolate areas of work to prevent contamination of clean or occupied spaces. Depending on the weather conditions, ventilate using 100% outside air to exhaust contaminated air directly to the outside during installation of VOC-emitting materials. Depressurize the work area allowing the air pressure differential between construction and clean areas to contain dust and odors. Provide temporary barriers that contain the construction area.

### Housekeeping

Institute cleaning activities designed to control contaminants in building spaces during construction and prior to occupancy. Porous building materials should be protected from exposure to moisture and stored in a clean area prior to installation. Some other strategies are using vacuum cleaners with high efficiency particulate filters, increasing the cleaning frequency and utilizing wetting agents for dust.

### Scheduling

Coordinate construction activities to minimize or eliminate disruption of operations in the occupied portions of the building. Construction activities over the duration of the project should be sequenced carefully to minimize the impact on the indoor air quality. It may be necessary to conduct activities with high pollution potential during off-hours, such as on the weekends or in the evenings to allow time for new materials to air out. Plan adequate time to complete work so flush-out and IAQ test procedures can be completed prior to occupancy. Upon completion of construction, replace all filtration media immediately prior to occupancy. This activity should be coordinated with the activities and requirements addressed in EQ Credit 3.2 and 5.

Utilizing temporary ventilation units is one strategy to meet the SMACNA control measure for HVAC protection, but does not on its own satisfy all of the requirements of this credit.

## Calculations

There are no calculations to support this credit.

## Exemplary Performance

This credit is not eligible for exemplary performance under the Innovation in Design section.

## Submittal Documentation

This credit is submitted as part of the **Construction Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

- ❑ Provide a copy of the project's Indoor Air Quality (IAQ) Management Plan.
- ❑ Confirm if the permanently installed air handling equipment was used during construction.
- ❑ Provide photos to highlight the implemented construction IAQ practices.
- ❑ List all filtration media (manufacturer, model #, MERV rating, location of installed filter) installed during construction and confirm that each was replaced prior to final occupancy.
- ❑ Provide an optional narrative describing any special circumstances or non-standard approaches taken by the project.

## Considerations

Building construction invariably introduces contaminates into the building. If unaddressed, the contamination can result in poor indoor air quality extending over the lifetime of the building. Fortunately there are IAQ management strategies, if instituted during construction and before occupancy, that will minimize potential problems.

### Environmental Issues

Contaminant reduction is beneficial to building occupants, resulting in greater comfort, lower absenteeism and greater productivity.

### Economic Issues

Superior indoor air quality is likely to increase worker productivity translating to greater profitability for companies. Additional time and labor may be required during construction to protect and clean ventilation systems and building spaces. However, these actions can extend the lifetime of the ventilation system and improve ventilation system efficiency, resulting in reduced energy use. The sequencing of material installation may require additional time and could potentially delay the date of initial occupancy. Early coordination between the contractor and subcontractors can minimize or eliminate scheduling delays.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**Controlling Pollutants and Sources**

**U.S. Environmental Protection Agency**

www.epa.gov/iaq/schooldesign/controlling.html

Detailed information on exhaust or spot ventilation practices during construction activity can be found toward the end of the webpage at the abovementioned URL address.

**The State of Washington (SOW) Program and IAQ Standards**

www.aerias.org/kview.asp?DocId=85&spaceid=2&subid=13

This IAQ standard for the state of Washington was the first state-initiated program to ensure the design of buildings with acceptable indoor air quality.

**Sheet Metal and Air Conditioning Contractors' National Association, Inc. (SMACNA)**

www.smacna.org

(703) 803-2980

SMACNA is a professional trade association that publishes the referenced standard as well as Indoor Air Quality: A Systems Approach, a comprehensive discussion of the sources of pollutants, measurement, methods of control, and management techniques.

### Print Media

*Indoor Air Quality*, Construction Technology Centre Atlantic. Written as a comprehensive review of indoor air quality issues and solutions, the report is available for purchase from http://ctca.unb.ca/CTCA/communication/IAQ/Order_IAQ.htm or by calling (506) 453-5000.

## Definitions

A **Construction IAQ Management Plan** is a document specific to a building project that outlines measures to minimize contamination in the building during construction and to flush the building of contaminants prior to occupancy.

**HVAC Systems** include heating, ventilating, and air-conditioning systems used to provide thermal comfort and ventilation for building interiors.

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|

Credit 3.2

1 point

# Construction IAQ Management Plan

## Before Occupancy

### Intent

Reduce indoor air quality problems resulting from the construction/renovation process in order to help sustain the comfort and well-being of construction workers and building occupants.

### Requirements

Develop and implement an Indoor Air Quality (IAQ) Management Plan for the pre-occupancy phase as follows:

OPTION 1 — FLUSH-OUT

- ❑ After construction ends, prior to occupancy and with all interior finishes installed, perform a building flush-out by supplying a total air volume of 14,000 cu.ft. of outdoor air per sq.ft. of floor area while maintaining an internal temperature of at least 60ºF and relative humidity no higher than 60%.

OR

- ❑ If occupancy is desired prior to completion of the flush-out, the space may be occupied following delivery of a minimum of 3,500 cu.ft. of outdoor air per sq.ft. of floor area to the space. Once a space is occupied, it shall be ventilated at a minimum rate of 0.30 cfm/sq.ft. of outside air or the design minimum outside air rate determined in EQ Prerequisite 1, whichever is greater. During each day of the flush-out period, ventilation shall begin a minimum of three hours prior to occupancy and continue during occupancy. These conditions shall be maintained until a total of 14,000 cu.ft./sq.ft. of outside air has been delivered to the space.

OR

OPTION 2 — AIR QUALITY TESTING

- ❑ Conduct baseline IAQ testing, after construction ends and prior to occupancy, using testing protocols consistent with the United States Environmental Protection Agency Compendium of Methods for the Determination of Air Pollutants in Indoor Air and as additionally detailed in this Reference Guide.
- ❑ Demonstrate that the contaminant maximum concentrations listed below are not exceeded.

| Contaminant | Maximum Concentration |
|---|---|
| Formaldehyde | 50 parts per billion |
| Particulates (PM10) | 50 micrograms per cubic meter |
| Total Volatile Organic Compounds (TVOC) | 500 micrograms per cubic meter |
| * 4-Phenylcyclohexene (4-PCH) | 6.5 micrograms per cubic meter |
| Carbon Monoxide (CO) | 9 part per million and no greater than 2 parts per million above outdoor levels |

** This test is only required if carpets and fabrics with styrene butadiene rubber (SBR) latex backing material are installed as part of the base building systems.*

- ❑ For each sampling point where the maximum concentration limits are exceeded conduct additional flush-out with outside air and retest the specific parameter(s) exceeded to indicate the requirements are achieved. Repeat procedure until all requirements have been met. When retesting non-complying building areas, take samples from the same locations as in the first test.
- ❑ The air sample testing shall be conducted as follows:
  1) All measurements shall be conducted prior to occupancy, but during normal occupied hours, and with the building ventilation system starting at the normal daily start time and operated at the minimum outside air flow rate for the occupied mode throughout the duration of the air testing.
  2) The building shall have all interior finishes installed, including but not limited to millwork, doors, paint, carpet and acoustic tiles. Non-fixed furnishings such as workstations and partitions are encouraged, but not required, to be in place for the testing.
  3) The number of sampling locations will vary depending upon the size of the building and number of ventilation systems. For each portion of the building served by a separate ventilation system, the number of sampling points shall not be less than one per 25,000 sq.ft., or for each contiguous floor area, whichever is larger, and include areas with the least ventilation and greatest presumed source strength.
  4) Air samples shall be collected between 3 feet and 6 feet from the floor to represent the breathing zone of occupants, and over a minimum 4-hour period.

### Potential Technologies & Strategies

Prior to occupancy, perform a building flush-out or test the air contaminant levels in the building. The flush-out is often used where occupancy is not required immediately upon substantial completion of construction. IAQ testing can minimize schedule impacts but may be more costly. Coordinate with EQ Credits 3.1 and 5 to determine the appropriate specifications and schedules for filtration media.

## Summary of Referenced Standard

**United States Environmental Protection Agency "Compendium of Methods for the Determination of Air Pollutants in Indoor Air"**

This standard is available from NTIS (800) 553-6847 with the ordering number PB90200288.

"The Compendium has been prepared to provide regional, state and local environmental regulatory agencies with step-by-step sampling and analysis procedures for the determination of selected pollutants in indoor air. Determination of pollutants in indoor air is a complex task, primarily because of the wide variety of compounds of interest and the lack of standardized sampling and analysis procedures. The Compendium has been prepared to provide a standardized format for such analytical procedures. A core set of ten chapters with each chapter containing one or more methods are presented in the current document. Compendium covers a variety of active and passive sampling procedures, as well as several analytical techniques both on and off site…" (Compendium of Methods for the Determination of Air Pollutants in Indoor Air Project Summary)

## Approach and Implementation

### Option 1—Flush-out Procedure

This compliance path uses the building HVAC system to evacuate airborne contaminants. The flush-out may begin only after all construction work is completed, including punch-list items. All cleaning should be finalized prior to flush-out. Final test and balancing should be completed and HVAC control should be functional, particularly if the occupants will be moving in during the second phase of flush-out. Commissioning may occur during flush-out provided it does not introduce any additional contaminants into the building.

The flush-out procedure discussed below assumes the use of the building's HVAC system, but alternatives are acceptable provided they meet the air quantity, temperature and humidity requirements.

One approach uses temporary supply and exhaust systems placed into windows or window openings. EPA's Indoor Air Quality for Schools website provides information on exhaust and spot ventilation during construction activities (see website information in the Resources section of this credit) that can be helpful for design teams who are considering using this approach. Care must be taken to ensure the airflow is not short circuited, potentially leaving remote corners within the project spaces with less than adequate circulation, or other parts of the building with unanticipated increases, such as a stack effect up elevator shafts.

If the space's central HVAC system is being used, remove any temporary filters and duct coverings installed as part of the Construction IAQ Management Plan. Replace the HVAC filtration media with new media; if the system is configured such that only outside air is filtered, these outside air filters do not need to be replaced. New filters which meet the design specification, installed prior to the start of flush-out, will satisfy the requirements of EQ Credit 3.1 as well. Note that these filters must be MERV 13 or better when a project plans to earn EQ Credit 5, Indoor Chemical and Pollution Source Control. Depending upon their condition following flush-out, some or all of the filters may be ready for replacement, but this is not a condition for satisfying the credit requirements.

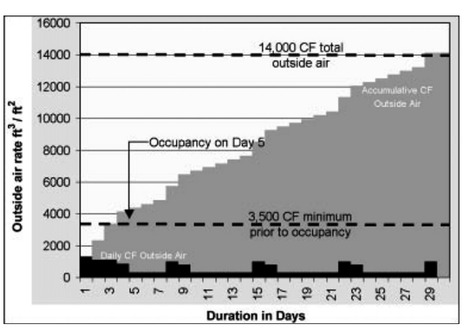
Outside air is used to dilute and remove off-gassed contaminants. The quantity of outside air that must be introduced to the project space for the flush-out is 14,000 cu.ft. of air per sq.ft. of floor area.

Occupants may move in earlier, after the point in the flush-out where 3,500 cu.ft. of air per sq.ft. has been reached. See **Graph 1** below. After the initial flush-out phase when 3,500 cu.ft. of outside air has been supplied per sq.ft. of floor area, the occupants may move in, but the flush-out is not complete. A total of 14,000 cu.ft. of outside air must be supplied per sq.ft. of floor area before switching the HVAC system to its normal operational mode.

Not all outside air is equal. Depending upon geography and season it can be very cold or damp. Because of this, prudent limits have been set to ensure no harm comes to the building and potentially to the occupants. The rate of outside air should not cause the interior temperature to drop below 60ºF and the relative humidity should not exceed 60%.

During an occupied flush-out phase, there is a minimum ventilation rate that must commence at least three hours prior to daily occupancy and continue while the space is occupied. The rate of outside air must be at least 0.30 cfm/sq.ft. or the design minimum outside air rate, whichever is greater. The design minimum outside air rate should be determined using ASHRAE Standard 62.1-2004, the same criteria for EQ Prerequisite 1, or the applicable local code if it is more stringent. The 0.30 cfm/sq.ft. rate may be several times that required by ASHRAE 62.1-2004 for a project's planned occupancy. As a result, consider the minimum flush-out rate during the early HVAC design process.

**Graph 1:** Sample Flush-out Procedure Air Quantity




There are other thermal comfort, expense and operational considerations to evaluate in conjunction with occupying a space before the end of flush-out. Check to make sure the HVAC system is capable of maintaining temperatures within a range acceptable to the occupants; opinions formed during this period may last long after the system is operating normally.

There are numerous expense and operational issues to be considered such as the rent or lease details, and the existing HVAC system capacity to accommodate the flush-out criteria. It is evident that input from nearly the entire project team is needed to determine the best approach. When completed, make the evaluation and the resulting flush-out strategy part of the project Construction IAQ Management Plan.

When there are multiple HVAC systems that can be operated independently, it is acceptable to flush out portions of the building as they are completed but no additional construction work is to occur once the flush-out of an area begins. Isolate completed areas from those under construction per SMACNA IAQ Guidelines for Occupied Buildings Under Construction.

When core and shell projects are certifying using the LEED-NC Rating System, they are not eligible to earn either EQ Credit 3.1 or 3.2 until all interior construction has been completed. Because the intent of these credits is to eliminate indoor air quality problems that occur as a result of construction, architectural finishes used in tenant build-outs—a significant source of air pollutants—must be addressed. If significant build-outs remain to be completed at the time of a LEED-NC certification review, EQ Credit 3.2 is not applicable unless the project includes specific design guidelines and protocols to implement the requirements of this credit in future build-outs. IAQ testing of one floor should not be presumed to be representative of other floors within a building.

### Option 2—Air Quality Testing

The baseline IAQ testing approach to credit compliance provides confirmation that major contaminants are below recognized acceptable levels prior to occupancy. While the list included in the credit is not intended to be all inclusive, together they approximate the major forms of airborne constituents found following construction. More explanation on the significance of each contaminant is provided in the Considerations section. Favorable test results are strong indicators that the project has implemented a successful construction IAQ management plan, that low-emitting materials have been specified, that cleanup has been thorough, and that the HVAC system is providing adequate ventilation. They also can mean that occupancy can occur potentially sooner than what might be possible if the flush-out compliance path has been followed. Ideally the groundwork for baseline testing should occur during the design process, making sure the testing requirements are included in Division 1 of the project construction specifications. This credit does not establish qualifications for the laboratory or those conducting the sampling. However, the project team should evaluate the capabilities of the IAQ specialist, industrial hygienist and testing facility being considered in the context of field sampling for IAQ in buildings. During construction, maintain vigilance to avoid substitutions of the specified low-emitting materials. Use low-VOC cleaning supplies to prevent short-term high VOC levels that may affect test results. Use vacuum cleaners with HEPA filtration to capture particulates.

Projects also following the requirements of LEED-NC EQ Credit 3.1 should replace all filtration media at this point. Finally, complete the air test and balancing of the HVAC system before beginning the baseline IAQ testing. The IAQ maximum contaminant levels are dependent on the HVAC system operating under normal conditions with outdoor air flow rates at the minimum; this stipulation is made so that the air tested is as similar as possible to what the occupants will be breathing. The protocols described in the referenced publication, U.S. EPA's "Compendium of Methods for the Determination of Air Pollutants in Indoor Air" are recommended, but others may be used if valid justification can be provided. The sampling locations should be selected carefully to ascertain the concentrations in areas with the least ventilation with potentially the greatest presumed contaminant source strength. Samples are to be taken in each portion of the building served by a separate ventilation system, and shall not be less then one per 25,000 sq.ft. For example, in a tenant space of 20,000 sq.ft. which is served by three rooftop units, one each for the north and south elevations (general office area), and the third for a training room and conference rooms, samples should be taken in at least three places, even though two of the units serve one general office area. The samples are to be taken in the breathing zone, between 3 feet and 6 feet above the floor. They are to be taken during normal occupied hours with the HVAC system operating with normal daily start times at the minimum outside air flow rate. Record the exact sample locations, since follow-up samples may be needed. If a test sample exceeds the maximum concentration level, flush out the space by increasing the rate of outside air. While the credit requirements do not prescribe the duration of the flush-out, those responsible for testing should make an evaluation based on the contaminant, its concentration and the potential source. The off-gassing characteristics of sources differ; some deplete rapidly while others emit at a steady rate over an extended period of time. Resample and confirm compliance before allowing the space to be occupied. The retest may be limited to the chemical contaminants that produced excessive chemical concentration levels in the initial test of the spaces.

## Calculations

There are no calculations associated with this credit.

## Exemplary Performance

This credit is not eligible for exemplary performance under the Innovation & Design section.

## Submittal Documentation

This credit is submitted as part of the **Construction Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

- ❑ Confirmation regarding the approach taken by the project (pre-occupancy flush-out; flush-out with early occupancy; IAQ testing)
- ❑ A copy of the project's Indoor Air Quality testing report (if applicable)
- ❑ A narrative describing the project's specific flush-out procedures and/or IAQ testing process and results

## Chemical Contaminants

### Formaldehyde

Formaldehyde is a gas emitted from numerous indoor sources. These include many building materials (especially pressed wood products such as particleboard, plywood, oriented strand board, fiberboard), glues and adhesives, most carpets, composite wood furnishings, permanent pressed fabrics, and combustion sources. Materials containing formaldehyde release formaldehyde gas into the air. Short term effects include eye, nose, throat and skin irritation; nausea; headache; allergic sensitization; and exacerbation of asthma. People vary substantially in their sensitivity to formaldehyde. For this credit, the maximum indoor concentration of 50 ppb of formaldehyde is an adaptation of a 1989 architectural specification for a group of buildings in the state of Washington. This specification required that each material in the building not contribute more than 50 ppb of formaldehyde to the indoor concentrations. For this credit the total emissions from all building materials must not result in an indoor concentration of formaldehyde greater than 50 ppb with the building ventilation system operating in the minimum outside air mode.

### Particulate Matter (PM10)

Airborne particulate matter is often generated in large quantities during construction. If dust control precautions are not undertaken during construction then reservoirs of construction dusts can remain on surfaces and especially within carpeted surfaces where the particles may be resuspended into the air by occupant activities for many months following construction. The outdoor air which enters the building can also be a significant source of indoor airborne particulate matter. The test samples particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers (PM10). For this credit the maximum indoor PM10 concentration of 50 μg/m3 is an adaptation of a 1989 architectural specification for a group of buildings in the state of Washington. This specification required that each material in the building not contribute more than 50 μg/m3 of PM10 to the indoor concentrations. For this credit the concentration of PM10 resulting from all indoor and outdoor sources must be less than 50 μg/m3 with the building ventilation system operating in the minimum outside air mode.

### TVOC, Total Volatile Organic Compounds

TVOC is the sum of all of the individual VOCs in the air. There are hundreds of individual VOCs emitted by materials in buildings. These include pressed wood products such as particleboard, plywood, oriented strand board, fiberboard, as well as glues and adhesives, paints, most carpets, composite wood furnishings, thermal insulation, and combustion sources. In addition, many volatile organic compounds are carcinogenic. For this credit, the maximum indoor TVOC concentration of 500 µg/m3 is an adaptation of an 1989 architectural specification for a group of buildings in the state of Washington. This specification required that each material in the building not contribute more than 500 µg/m3 of TVOC to the indoor concentrations. For this credit the total emissions from all building materials must not result in an indoor concentration greater than 500 µg/m3 with the building ventilation system operating in the minimum outside air mode.

### 4-PCH, 4-phenylcyclohexene

This compound, whose odor is easily detectable at very low levels, is generally known as "new carpet" odor. It is emitted from the styrene butadiene rubber (SBR) binder that some manufacturers used to hold carpet fibers and backing together. For this credit, the maximum indoor 4-PCH concentration of 6.5 µg/m3 is an adaptation of a 1989 architectural specification for a group of buildings in the state of Washington. This specification required that each material in the building not contribute more than 6.5 µg/m3 of 4-PCH to the indoor concentrations. For this credit the total emissions from all building materials must not result in an indoor concentration greater than 6.5 µg/m3 of 4-PCH with the building ventilation system operating in the minimum outside air mode. This test may be waived if there are no carpets or fabrics containing SBR.

### Carbon Monoxide (CO)

Carbon monoxide is a colorless, odorless and tasteless gas. It is a product of incomplete combustion, emitted from sources such as vehicle exhaust, gas and propane device exhaust, wood stoves, kerosene heaters and cigarettes. For this credit the maximum indoor CO concentration of 9 ppm is from the EPA National Primary and Secondary Ambient Air Quality Standards, Code of Federal Regulations, Title 40 Part 50 (40CFR50), as amended July 1, 1987. A summary of the Primary Standards is included in ASHRAE 62-2001, Table 1. In addition, a concentration of no more than 2 ppm over outdoor concentrations is required, as this indicates a source of this potentially lethal gas in the building.

## Considerations

### Economic Issues

Superior indoor air quality is likely to increase worker productivity translating to greater profitability for companies. Additional time and labor may be required during and after construction to protect and clean ventilation systems. However, these actions can extend the lifetime of the ventilation system and improve ventilation system efficiency, resulting in reduced energy use. The sequencing of material installation may require additional time and could potentially delay the date of initial occupancy. Early coordination between the contractor and subcontractors can minimize or eliminate scheduling delays.

### Community Issues

Contaminants from the construction process can affect the health of construction workers during construction and building users during occupancy. If contaminants remain after occupancy commences, they may lead to expensive and complicated clean-up procedures. Construction worker health is covered by federal and state regulations, primarily the Occupational Safety and Health Administration (OSHA). However, building occupants are not covered under these regulations.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**Indoor Air Pollution Report (July, 2005)**

**California Air Resources Board**

www.arb.ca.gov/research/indoor/ab1173/finalreport.htm

**Controlling Pollutants and Sources, IAQ Design for Schools**

**U.S. Environmental Protection Agency**

www.epa.gov/iaq/schooldesign/controlling.html

Detailed information on exhaust or spot ventilation practices during construction activity can be found toward the end of the webpage at the abovementioned URL address.

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**Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air**

**U.S. Environmental Protection Agency**

This standard is available from NTIS (800) 553-6847 with the ordering number PB90200288.

## Definitions

A **Construction IAQ Management Plan** is a document specific to a building project that outlines measures to minimize contamination in the building during construction and to flush the building of contaminants prior to occupancy.

**HVAC Systems** include heating, ventilating, and air-conditioning systems used to provide thermal comfort and ventilation for building interiors.

## Case Study

### Toyota Portland Vehicle Distribution Center

Owner: Toyota Motor Corporation

Photo © Rick Keating, Courtesy of ASD

The Toyota Portland Vehicle Distribution Center is a LEED-NC v2.0 Gold Certified building, which was designed in accordance with SMACNA guidelines. The design team executed numerous strategies to protect absorptive materials from moisture and to prevent construction debris and dust from entering the duct/ventilation system. The team also undertook HVAC protection, source control, interruption of contamination pathways, and housekeeping of the facility, and scheduled construction to avoid off-gassing. Toyota Real Estate and Facilities (RE&F) is committed to providing Toyota associates with an enjoyable and healthy atmosphere.

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|

Credit 4.1

1 point

# Low-Emitting Materials

## Adhesives & Sealants

### Intent

Reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

### Requirements

All adhesives and sealants used on the interior of the building (defined as inside of the weatherproofing system and applied on-site) shall comply with the requirements of the following reference standards:

- Adhesives, Sealants and Sealant Primers: South Coast Air Quality Management District (SCAQMD) Rule #1168. VOC limits are listed in the table below and correspond to an effective date of July 1, 2005 and rule amendment date of January 7, 2005.

**Table 1:** SCAQMD VOC Limits

| Architectural Applications | VOC Limit [g/L less water] | Specialty Applications | VOC Limit [g/L less water] |
|---|---|---|---|
| Indoor Carpet Adhesives | 50 | PVC Welding | 510 |
| Carpet Pad Adhesives | 50 | CPVC Welding | 490 |
| Wood Flooring Adhesives | 100 | ABS Welding | 325 |
| Rubber Floor Adhesives | 60 | Plastic Cement Welding | 250 |
| Subfloor Adhesives | 50 | Adhesive Primer for Plastic | 550 |
| Ceramic Tile Adhesives | 65 | Contact Adhesive | 80 |
| VCT & Asphalt Adhesives | 50 | Special Purpose Contact Adhesive | 250 |
| Drywall & Panel Adhesives | 50 | Structural Wood Member Adhesive | 140 |
| Cove Base Adhesives | 50 | Sheet Applied Rubber Lining Operations | 850 |
| Multipurpose Construction Adhesives | 70 | Top & Trim Adhesive | 250 |
| Structural Glazing Adhesives | 100 | | |
| | | | |
| **Substrate Specific Applications** | **VOC Limit [g/L less water]** | **Sealants** | **VOC Limit [g/L less water]** |
| Metal to Metal | 30 | Architectural | 250 |
| Plastic Foams | 50 | Nonmembrane Roof | 300 |
| Porous Material (except wood) | 50 | Roadway | 250 |
| Wood | 30 | Single-Ply Roof Membrane | 450 |
| Fiberglass | 80 | Other | 420 |
| | | | |
| | | **Sealants** | **VOC Limit [g/L less water]** |
| | | Architectural Non Porous | 250 |
| | | Architectural Porous | 775 |
| | | Other | 750 |

**Table 2:** Greenseal VOC Limits

| Aerosol Adhesives | VOC Weight [g/L minus water] |
|---|---|
| General purpose mist spray | 65% VOCs by weight |
| General purpose web spray | 55% VOCs by weight |
| Special purpose aerosol adhesives (all types) | 70% VOCs by weight |

- ❑ Aerosol Adhesives: Green Seal Standard for Commercial Adhesives GS-36 requirements in effect on October 19, 2000.

## Potential Technologies & Strategies

Specify low-VOC materials in construction documents. Ensure that VOC limits are clearly stated in each section of the specifications where adhesives and sealants are addressed. Common products to evaluate include general construction adhesives, flooring adhesives, fire-stopping sealants, caulking, duct sealants, plumbing adhesives, and cove base adhesives.

## Summary of Referenced Standards

**South Coast Rule #1168 October 3, 2003 Amendment by the South Coast Air Quality Management District**

South Coast Air Quality Management District

www.aqmd.gov/rules/reg/reg11/r1168.pdf

(909) 396-2000

The South Coast Air Quality Management District is a governmental organization in Southern California with the mission to maintain healthful air quality for its residents. The organization established source specific standards to reduce air quality impacts. The South Coast Rule #1168 VOC limits for adhesives are summarized above in **Table 1**.

**Green Seal Standard 36 (GS-36), Effective October 19, 2000**

www.greenseal.org/standards/commercialadhesives.htm

Green Seal is an independent nonprofit organization that promotes the manufacture and sale of environmentally responsible consumer products. GS-36 is a standard that sets VOC limits for commercial adhesives.

## Approach and Implementation

See the supplemental section at the end of this credit for all EQ Credit 4 instructions.

## Calculations

There are no calculations associated with this credit.

## Exemplary Performance

This credit is not eligible for exemplary performance under the Innovation in Design section.

## Submittal Documentation

This credit is submitted as part of the **Construction Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

- ❑ Provide a listing of each indoor adhesive, sealant and sealant primer product used on the project. Include the manufacturer's name, product name, specific VOC data (in g/L, less water) for each product, and the corresponding allowable VOC from the referenced standard.
- ❑ Provide a listing of each indoor aerosol adhesive product used on the project. Include the manufacturer's name, product name, specific VOC data (in g/L, less water) for each product, and the corresponding allowable VOC from the referenced standard.
- ❑ Provide a narrative to describe any special circumstances or non-standard compliance paths taken by the project.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**South Coast Rule #1168 by the South Coast Air Quality Management District**

**South Coast Air Quality Management District**

www.aqmd.gov/rules

(909) 396-2000

The South Coast Air Quality Management District is a governmental organization in Southern California with the mission to maintain healthful air quality for its residents. The organization established source specific standards to reduce air quality impacts. The South Coast Rule #1168 VOC limits for adhesives are summarized above in **Table 1**.

**Green Seal Standard 36 (GS-36)**

www.greenseal.org/standards/commercialadhesives.htm

Green Seal is an independent nonprofit organization that promotes the manufacture and sale of environmentally responsible consumer products. GS-36 is a standard that sets VOC limits for commercial adhesives.

## Definitions

**Adhesive** is any substance that is used to bond one surface to another surface by attachment. Adhesives include adhesive bonding primers, adhesive primers, adhesive primers for plastics, and any other primer.

**Aerosol Adhesive** is an adhesive packaged as an aerosol product in which the spray mechanism is permanently housed in a non-refillable can designed for hand-held application without the need for ancillary hoses or spray equipment. Aerosol adhesives include special purpose spray adhesives, mist spray adhesives and web spray adhesives.

**Indoor Adhesive**, **Sealant** and/or **Sealant Primer** product is defined as an adhesive or sealant product applied on-site, inside of the building's weatherproofing system.

**Porous Sealant** is a substance used as a sealant on porous materials. Porous materials have tiny openings, often microscopic, in which fluids may be absorbed or discharged. Such materials include, but are not limited to, wood, fabric, paper, corrugated paperboard and plastic foam.

**Primer** is a material applied to a substrate to improve adhesion of subsequently applied adhesive.

**Non-porous Sealant** is a substance used as a sealant on non-porous materials. Non-porous materials do not have openings in which fluids may be absorbed or discharged. Such materials include, but are not limited to, plastic and metal.

A **Sealant** is any material with adhesive properties that is formulated primarily to fill, seal, or waterproof gaps or joints between two surfaces. Sealants include sealant primers and caulks.

**VOC** (Volatile Organic Compounds) are carbon compounds that participate in atmospheric photochemical reactions (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides and carbonates, and ammonium carbonate). The compounds vaporize (become a gas) at normal room temperatures.

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|

Credit 4.2

1 point

# Low-Emitting Materials

## Paints & Coatings

### Intent

Reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

### Requirements

Paints and coatings used on the interior of the building (defined as inside of the weatherproofing system and applied on-site) shall comply with the following criteria:

- ❑ Architectural paints, coatings and primers applied to interior walls and ceilings: Do not exceed the VOC content limits established in Green Seal Standard GS-11, Paints, First Edition, May 20, 1993.
  - Flats: 50 g/L
  - Non-Flats: 150 g/L
- ❑ Anti-corrosive and anti-rust paints applied to interior ferrous metal substrates: Do not exceed the VOC content limit of 250 g/L established in Green Seal Standard GC-03, Anti-Corrosive Paints, Second Edition, January 7, 1997.
- ❑ Clear wood finishes, floor coatings, stains, sealers, and shellacs applied to interior elements: Do not exceed the VOC content limits established in South Coast Air Quality Management District (SCAQMD) Rule 1113, Architectural Coatings, rules in effect on January 1, 2004.
  - Clear wood finishes: varnish 350 g/L; lacquer 550 g/L
  - Floor coatings: 100 g/L
  - Floor coatings: 100 g/L
  - Sealers: waterproofing sealers 250 g/L; sanding sealers 275 g/L; all other sealers 200 g/L
  - Stains: 250 g/L

### Potential Technologies & Strategies

Specify low-VOC paints and coatings in construction documents. Ensure that VOC limits are clearly stated in each section of the specifications where paints and coatings are addressed. Track the VOC content of all interior paints and coatings during construction.

## Summary of Referenced Standards

**Green Seal Standard GS-11**

www.greenseal.org/standards/paints.htm

(202) 872-6400

Green Seal is an independent nonprofit organization that promotes the manufacture and sale of environmentally responsible consumer products. GS-11 is a standard that sets VOC limits for commercial flat and non-flat paints.

**Green Seal Standard GS-03**

www.greenseal.org/standards/anti-corrosivepaints.htm

(202) 872-6400

GS-03 is a Green Seal standard that sets VOC limits for anti-corrosive and anti-rust paints.

**South Coast Air Quality Management District (SCAQMD) Rule 1113, Architectural Coatings**

www.aqmd.gov/rules

The South Coast Air Quality Management District is a governmental organization in Southern California with the mission to maintain healthful air quality for its residents. The organization established source specific standards to reduce air quality impacts.

## Approach and Implementation

See the supplemental section at the end of this credit for all EQ Credit 4 instructions.

## Calculations

There are no calculations associated with this credit.

## Exemplary Performance

This credit is not eligible for exemplary performance under the Innovation & Design section.

## Submittal Documentation

This credit is submitted as part of the **Construction Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

- ❑ Provide a listing of each indoor paint and coating used on the project. Include the manufacturer's name, product name, specific VOC data (in g/L) for each product, and the corresponding allowable VOC from the referenced standard.
- ❑ Provide a narrative to describe any special circumstances or non-standard compliance paths taken by the project.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**Green Seal**

www.greenseal.org

**South Coast Air Quality Management District**

www.aqmd.gov

## Definitions

**Anti-corrosive Paints** are coatings formulated and recommended for use in preventing the corrosion of ferrous metal substrates.

**Paint** is a liquid, liquefiable or mastic composition that is converted to a solid protective, decorative, or functional adherent film after application as a thin layer. These coatings are intended for on-site application to interior or exterior surfaces of residential, commercial, institutional or industrial buildings.

**Indoor Paint** or **Coating Product** is defined as a paint or coating product applied on-site inside of the building's weatherproofing system.

**Flat Coatings** are coatings that register a gloss of less than 15 on an 85-degree meter or less than 5 on a 60-degree meter.

**Non-flat Coatings** are coatings that register a gloss of 5 or greater on a 60-degree meter and a gloss of 15 or greater on an 85-degree meter.

**Primer** is a material applied to a substrate to improve adhesion of subsequently applied adhesive.

**VOCs** (Volatile Organic Compounds) are carbon compounds that participate in atmospheric photochemical reactions (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides and carbonates, and ammonium carbonate). The compounds vaporize (become a gas) at normal room temperatures.

1 point

# Low-Emitting Materials

## Carpet Systems

### Intent

Reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

### Requirements

All carpet installed in the building interior shall meet the testing and product requirements of the Carpet and Rug Institute's Green Label Plus program.

All carpet cushion installed in the building interior shall meet the requirements of the Carpet and Rug Institute Green Label program.

All carpet adhesive shall meet the requirements of EQ Credit 4.1: VOC limit of 50 g/L.

### Potential Technologies & Strategies

Clearly specify requirements for product testing and/or certification in the construction documents. Select products that are either certified under the Green Label Plus program or for which testing has been done by qualified independent laboratories in accordance with the appropriate requirements.

The Green Label Plus program for carpets and its associated VOC emission criteria in micrograms per square meter per hour, along with information on testing method and sample collection developed by the Carpet & Rug Institute (CRI) in coordination with California's Sustainable Building Task Force and the California Department of Health Services (DHS), are described in Section 9, Acceptable Emissions Testing for Carpet, DHS Standard Practice CA/DHS/EHLB/R-174, dated 07/15/04. This document is available at: www.dhs.ca.gov/ps/deodc/ehlb/iaq/VOCS/Section01350_7_15_2004_FINAL_PLUS_ADDENDUM-2004-01.pdf (also published as Section 01350 Section 9 [dated 2004] by the Collaborative for High Performance Schools [www.chps.net]).

## Summary of Referenced Standard

**Carpet and Rug Institute Green Label Plus Testing Program**

Carpet and Rug Institute

www.carpet-rug.com

(800) 882-8846

The Carpet and Rug Institute is a trade organization representing the carpet and rug industry. Green Label Plus is an independent testing program that identifies carpets with very low emissions of volatile organic compounds (VOCs). The "Green Label Plus" program for carpets and its associated VOC emission criteria in micrograms per square meter per hour developed by the Carpet & Rug Institute (CRI) in coordination with California's Sustainable Building Task Force and the California Department of Health Services (DHS) are described on the CRI website. In the CRI Green Label Plus Program, emission rates must be verified by conducting annual testing. Valid/approved certification numbers can be reviewed on the CRI website under Indoor Air Quality/Green Label Plus/Approved companies. Approved products are listed under the company heading.

## Testing Criteria

Carpet must not exceed the maximum target emission factors used in the CRI Green Label program and following the test protocol used by Green Label Plus. Test results submitted must be no more than 2 years old at the time of submission. Standard Practice for the Testing of Volatile Organic Emissions from Various Sources using Small-Scale Environmental Chambers (State of California Standard 1350), Section 9

www.dhs.ca.gov/ps/deodc/ehlb/iaq/VOCS/Section01350_7_15_2004_FINAL_PLUS_ADDENDUM-2004-01.pdf

This standard practice document specifies testing criteria for carpet emissions that will satisfy the credit requirements.

## Approach and Implementation

See the supplemental section at the end of this credit for all EQ Credit 4 instructions.

## Calculations

There are no calculations associated with this credit.

## Exemplary Performance

This credit is not eligible for exemplary performance under the Innovation in Design section.

## Submittal Documentation

This credit is submitted as part of the **Construction Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

- ❑ Provide a listing of each carpet product installed in the building interior. Confirm that the product complies with the CRI Green Label Plus testing program.
- ❑ Provide a listing of each carpet cushion product installed in the building interior. Confirm that the product complies with the CRI Green Label testing program.
- ❑ Provide a narrative to describe any special circumstances or non-standard compliance paths taken by the project.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**Carpet and Rug Institute**

www.carpet-rug.org

## Definitions

**Indoor carpet systems** are defined as carpet, carpet adhesive, or carpet cushion product installed on-site inside of the building's weatherproofing system.

**VOCs** (Volatile Organic Compounds) are carbon compounds that participate in atmospheric photochemical reactions (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides and carbonates, and ammonium carbonate). The compounds vaporize (become a gas) at normal room temperatures.

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|

Credit 4.4

1 point

# Low-Emitting Materials

## Composite Wood & Agrifiber Products

### Intent

Reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

### Requirements

Composite wood and agrifiber products used on the interior of the building (defined as inside of the weatherproofing system) shall contain no added urea-formaldehyde resins. Laminating adhesives used to fabricate on-site and shop-applied composite wood and agrifiber assemblies shall contain no added urea-formaldehyde resins.

Composite wood and agrifiber products are defined as: particleboard, medium density fiberboard (MDF), plywood, wheatboard, strawboard, panel substrates and door cores. Materials considered fit-out, furniture, and equipment (FF&E) are not considered base building elements and are not included.

### Potential Technologies & Strategies

Specify wood and agrifiber products that contain no added urea-formaldehyde resins. Specify laminating adhesives for field and shop applied assemblies that contain no added urea-formaldehyde resins.

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|
| Credit 4.4 | | | | | |

## Summary of Referenced Standard

There is no standard referenced for this credit.

## Approach and Implementation

See the supplemental section at the end of this credit for all EQ Credit 4 instructions.

## Calculations

There are no calculations associated with this credit.

## Exemplary Performance

This credit is not eligible for exemplary performance under the Innovation in Design section.

## Submittal Documentation

This credit is submitted as part of the **Construction Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

- ❑ Provide a listing of each composite wood and agrifiber product installed in the building interior. Confirm that each product does not contain any added urea-formaldehyde.
- ❑ Provide a narrative to describe any special circumstances or non-standard compliance paths taken by the project.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**An Update on Formaldehyde**

**Consumer Product Safety Commission**

www.cpsc.gov/CPSCPUB/PUBS/725.html

An informational document from the Consumer Product Safety Commission.

### Definitions

**Agrifiber Board** is a composite panel product derived from recovered agricultural waste fiber from sources including, but not limited to, cereal straw, sugarcane bagasse, sunflower husk, walnut shells, coconut husks, and agricultural prunings. The raw fibers are processed and mixed with resins to produce panel products with characteristics similar to those derived from wood fiber. The following conditions describe which products must comply with the requirements:

1. The product is inside of the building's waterproofing system.
2. Composite components used in assemblies are to be included (e.g., door cores, panel substrates, etc.)
3. The product is part of the base building systems.

**Composite Wood** is a product consisting of wood or plant particles or fibers bonded together by a synthetic resin or binder. Examples: plywood, particle-board, OSB, MDF, composite door cores. For the purposes of this credit, the following conditions describe which products must comply with the requirements:

1. The product is inside of the building's waterproofing system.
2. Composite wood components used in assemblies are included (e.g., door cores, panel substrates, plywood sections of I-beams).
3. The product is part of the base building systems.

**Formaldehyde** is a naturally occurring VOC found in small amounts in animals and plants, but is carcinogenic and an irritant to most people when present in high concentrations—causing headaches, dizziness, mental impairment, and other symptoms. When present in the air at levels above 0.1 ppm parts of air, it can cause watery eyes, burning sensations in the eyes, nose and throat; nausea; coughing; chest tightness; wheezing; skin rashes; and asthmatic and allergic reactions.

**Indoor Composite Wood or Agrifiber** product is defined as a composite wood or agrifiber product installed on-site inside of the building's weatherproofing system.

**Laminate Adhesive** is an adhesive used in wood/agrifiber products (veneered panels, composite wood products contained in engineered lumber, door assemblies, etc.).

**Urea Formaldehyde** is a combination of urea and formaldehyde that is used in some glues and may emit formaldehyde at room temperature.

**Phenol Formaldehyde**, which off-gasses only at high temperature, is used for exterior products, although many of those products are suitable for interior applications.

# Supplemental Information

## Approach and Implementation

The four parts of LEED-NC EQ Credit 4 apply to products and installation processes that have the potential to adversely affect the indoor air quality (IAQ) of a project space and, in turn, those exposed to the contaminants these materials may off-gas.

## Strategies

The requirements for products and activities covered in EQ Credit 4 should be noted in the project specifications and, ideally, within the specific section of the document applicable to a particular trade or supplier.

### Design Phase

In order to achieve this goal, credit requirements should be clearly stated in project specifications. Reference the credit requirements in both Division 1 and in the technical divisions. Indicate what must be provided in the way of cut sheets, material safety data sheets (MSD sheets), certificates and test reports. Consider making submittal of this compliance documentation a condition of product approval.

### Construction Phase

Meeting the requirements set in EQ Credit 4 is not everyday practice for all construction teams and suppliers. Consider asking the project owner to stress the importance of meeting the LEED requirements during pre-bid meetings and again at the time of contract award. During these sessions, have LEED Accredited Professionals available and ask for questions. Include requirements in subcontract and purchase order language.

### Composition Limits

All materials that emit contaminants that have the potential to enter the indoor air will be considered as indoor sources of contaminants. Materials which have the potential to communicate their emissions to the indoor air include all indoor surfaces in contact with the indoor air including flooring; walls; ceilings; interior furnishings; suspended ceiling systems and the materials above those suspended ceilings; all ventilation system components in communication with the ventilation supply or return air; and all materials inside of wall cavities, ceiling cavities, floor cavities, or horizontal or vertical chases. These materials include the caulking materials for windows and insulation in ceilings or walls. An example of a material that has little or no potential for communicating with the indoor air is siding that is on the exterior side of the waterproofing membrane. In this approach the formulation of a product is controlled. Limits are set on the amount of volatile organic compounds (VOCs) permitted in a given volume of the product. The threshold limits and the content within a particular product are generally expressed in grams per liter (g/L). EQ Credits 4.1 and 4.2 use this approach for adhesives, sealants, paints and coatings. EQ Credit 4.4 also controls formulation by setting a limit of zero added urea-formaldehyde resins.

### Emission Factors

This standard sets a limit on the rate that off-gassing may occur. The rate is stated as the mass of contaminant that may be off-gassed by a given unit quantity of the product in a set period of time. This approach is used in EQ Credit 4.3 for carpet where the rate is expressed as micrograms of contaminant per square meter of carpet per hour. These tests, which are now being done on an array of product types, place samples of precise size in test chambers.

Air samples are drawn off at set times, generally over several days, and analyzed. There are extensive protocols established to make the testing representative of actual conditions on a project site and consistent between similar products from multiple manufactures. The Carpet and Rug Institute (CRI) Green Label Plus program uses emission factor test results for its certifications.

### VOC Budgets

This alternative compliance path allows for specialty applications for which there is no low-VOC product option. It may be used with adhesives and sealants covered in EQ Credit 4.1 and with paints and coatings covered in EQ Credit 4.2. The documentation must demonstrate that the overall low-VOC performance has been attained for paints and adhesives separately, not in combination. The calculation is a comparison between a baseline case and the design case. When the design (or actual) is less than the baseline, the credit requirement is satisfied. The values used in the comparison are the total VOCs contained in the products (i.e., paint) used on the project. The total VOCs is determined by multiplying the volume of the product used by the threshold VOC level for the baseline case and actual product VOC level for the design case. The baseline application rate should not be greater than that used in the design case. When submitting a VOC budget calculation, also provide the supporting documentation concerning the product—the name, application rate, class or use to confirm that the correct threshold VOC level has been used in determining the baseline case, and finally the actual VOC level of the product. As the term "budget" implies, this compliance path should be a decision planned in advance. Occasionally, honest mistakes occur—even on LEED projects. If realized in time, this approach may be used to determine if credit compliance can be attained. A narrative explaining the situation should accompany the project submittal, but project teams should never "paint" their way out of a mistake. Additional coats, even with products below the threshold limits, add to the overall level of off-gassed VOCs. It is not enough to meet the requirements; the intent also has to be met to earn the credit.

## Considerations

A large number of building products contain compounds that have a negative impact on indoor air quality and the Earth's atmosphere. The most prominent of these compounds, volatile organic compounds (VOCs), contribute to smog generation and air pollution outdoors while having an adverse effect on the well-being of building occupants indoors. By selecting low-emitting materials, both outdoor and indoor air quality impacts can be reduced.

### Environmental Issues

VOCs react with sunlight and nitrogen oxides in the atmosphere to form ground-level ozone, a chemical that has a detrimental effect on human health, agricultural crops, forests and ecosystems. Ozone damages lung tissue, reduces lung function, and sensitizes the lungs to other irritants. Ozone is also a major component of smog, which affects agricultural crops and forestland.

### Economic Issues

Healthy occupants are more productive and have less illness-related absenteeism. Use of high-VOC content materials can cause illness and may decrease occupant productivity. These problems result in increased expenses and liability for building owners, operators and insurance companies. As a result, the construction market is driving product manufacturers to offer low-VOC alternatives to conventional building products. Costs for these low-VOC products are generally competitive with conventional materials. However, some low-VOC materials are more expensive than conventional materials, particularly when the products are first introduced to the marketplace. Low-VOC products may also be difficult to obtain for some product types. However, these problems will recede as application of low-VOC products become more commonplace.

### Synergies and Trade-Offs

Selecting materials that are low in VOCs helps reduce sources of pollutants during the construction process and in the finished building. There are typically multiple products available that meet these criteria for a wide variety of applications. However, these criteria must be balanced against other green building considerations, such as location of manufacture, durability and performance.

## Case Study

**David Lawrence Convention Center**

**Pittsburgh, PA**

Owner: Pittsburgh Sports & Exhibition Authority

Photo © Brad Feinknopf

On November 7, 2003, the David L. Lawrence Convention Center in Pittsburgh, PA achieved LEED® v2.0 Gold. Home to the USGBC's second annual Greenbuild International Conference & Expo, the 1,486,000 square foot project is the first LEED certified convention center in the world. The project attained each of the four low-emitting materials credits through the use of low- or no-VOC adhesives and paints, low-emitting carpet, and composite wood with no added urea formaldehyde—all of which contribute to a healthier indoor environment for meeting attendees.

# Indoor Chemical & Pollutant Source Control

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|

Credit 5

1 point

## Intent

Minimize exposure of building occupants to potentially hazardous particulates and chemical pollutants.

## Requirements

Design to minimize and control pollutant entry into buildings and later cross-contamination of regularly occupied areas:

- ❑ Employ permanent entryway systems at least six feet long in the primary direction of travel to capture dirt and particulates from entering the building at all entryways that are directly connected to the outdoors. Acceptable entryway systems include permanently installed grates, grilles, or slotted systems that allow for cleaning underneath. Roll-out mats are only acceptable when maintained on a weekly basis by a contracted service organization. Qualifying entryways are those that serve as regular entry points for building users.
- ❑ Where hazardous gases or chemicals may be present or used (including garages, housekeeping/laundry areas and copying/printing rooms), exhaust each space sufficiently to create negative pressure with respect to adjacent spaces with the doors to the room closed. For each of these spaces, provide self-closing doors and deck to deck partitions or a hard lid ceiling. The exhaust rate shall be at least 0.50 cfm/sq.ft., with no air re-circulation. The pressure differential with the surrounding spaces shall be at least 5 Pa (0.02 inches of water gauge) on average and 1 Pa (0.004 inches of water) at a minimum when the doors to the rooms are closed.
- ❑ In mechanically ventilated buildings, provide regularly occupied areas of the building with air filtration media prior to occupancy that provides a Minimum Efficiency Reporting Value (MERV) of 13 or better. Filtration should be applied to process both return and outside air that is to be delivered as supply air.

## Potential Technologies & Strategies

Design facility cleaning and maintenance areas with isolated exhaust systems for contaminants. Maintain physical isolation from the rest of the regularly occupied areas of the building. Install permanent architectural entryway systems such as grilles or grates to prevent occupant-borne contaminants from entering the building. Install high-level filtration systems in air handling units processing both return air and outside supply air. Ensure that air handling units can accommodate required filter sizes and pressure drops.

## Summary of Referenced Standard

**ANSI/ASHRAE 52.2-1999: Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size**, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

www.ashrae.org

(800) 527-4723

This standard presents methods for testing air cleaners for two performance characteristics: the ability of the device to remove particles from the air stream and the device's resistance to airflow. The minimum efficiency reporting value (MERV) is based on three composite average particle size removal efficiency (PSE) points. Consult the standard for a complete explanation of MERV value calculations. **Table 1** summarizes the requirements for a MERV value of 13.

## Approach and Implementation

The indoor air quality of buildings is adversely affected by seemingly benign activities of daily occupancy and operations. Occupants and building visitors contribute to IAQ issues within buildings by tracking in contaminants on their shoes and clothing. Daily copier, fax and printer operations add contaminants to the building's interior environment. Additionally, the storage, mixing and disposal of housekeeping liquids may adversely affect the health and productivity of building occupants. This credit strives to improve indoor environmental conditions by mitigating the amount of particulate, chemical and biological contaminants that occupants are exposed to inside buildings.

Incorporate permanent entryway systems, which remove debris from shoes, at all high-traffic exterior access points to reduce the amount of contaminants tracked into the occupied space by people. The entryway systems should be designed to capture and remove particles from shoes without allowing build-up of contaminants. Open grates/grilles or other entryway systems that have a recessed collection area are generally thought to be most effective. (Carpeted systems are not regarded as providing the same effectiveness in particulate removal as open grid type systems and require continuous cleaning/maintenance to avoid build-up of dirt and debris.)

Locate high-volume copy, print and fax equipment away from occupant work spaces in enclosed rooms with self-closing doors. In order to effectively remove airborne contaminants generated by this type of equipment, the rooms must be physically separated from adjacent spaces. This may be accomplished through installation of deck to deck partitions or sealed gypsum board enclosures. Rooms with large openings but no doors will not be able to meet the credit requirement. To remove airborne contaminants, and prevent cross-contamination into occupied spaces, copy, print and/or fax rooms must be equipped with a dedicated exhaust system (no return air) that creates a negative pressure within the room meeting the requirements of this credit. Convenience (small) copier and printer use should be minimized where possible. Although encouraged, designing exhaust systems that account for convenience copier and printer use is not a required part of this credit.

**Table 1:** Requirements for a MERV Value 13

| Composite Average Particle Size Efficiency [%] | | | Minimum Final Resistance | |
|---|---|---|---|---|
| 0.30 – 1.0 μm | 1.0 – 3.0 μm | 3.0 – 10.0 μm | [Pa] | [in. of water] |
| < 75% | ≥90% | ≥90% | 350 | 1.4 |

Chemical storage and mixing areas, such as janitor's closets and photo labs should also be located away from occupant work areas. Additionally, these rooms must be physically separated from adjacent spaces via installation of deck-to-deck partitions or sealed gypsum board enclosures. Rooms must be equipped with a dedicated exhaust system (no return air) that creates the required negative pressurization to ensure that cross contamination into adjacent occupied spaces will not occur.

All building HVAC systems must be designed to accommodate filtration systems with a minimum MERV 13 rating.

Additional ventilation systems to mitigate contaminating space activities may affect building energy performance and require commissioning and Measurement & Verification attention. Ventilation system design will also be affected to ensure that installed systems are capable of accommodating filtration media required for credit compliance. This may be difficult to achieve for spaces with low capacity, packaged air handling systems, due to the size of these filters and their associated pressure drop. The selected space layout may prohibit deck-to-deck separation and separate ventilation systems for chemical use areas. Storage areas for recyclable materials may also be considered to be contaminant sources, depending on the items recycled. Janitorial supplies may impact indoor air quality if not wisely chosen.

## Calculations

There are no specific calculations associated with this credit.

## Exemplary Performance

This credit is not eligible for exemplary performance under the Innovation in Design section.

## Submittal Documentation

This credit is submitted as part of the **Design Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

- ❑ Provide confirmation that required entryway systems have been provided.
- ❑ Provide a listing of each entryway product installed in the building. For roll-up or carpeted systems, confirm that the required contracted maintenance will take place.
- ❑ Provide copies of the project's construction drawings to highlight the location of the installed entryway systems.
- ❑ Confirm that chemical use areas have been designed as separate rooms with dedicated exhaust systems and appropriate negative pressurization.
- ❑ Provide copies of the project's mechanical drawings to highlight the location of chemical usage areas, room separations, and the associated exhaust systems.
- ❑ If mechanically ventilated, confirm that the installed filters have a MERV rating of 13 or better.
- ❑ Provide a listing of the installed filters and their associated MERV ratings.
- ❑ Provide a narrative to describe any special circumstances or non-standard compliance paths taken by the project.

## Considerations

### Cost Issues

Additional sinks, drains, room separations, and separate exhausts for copying and housekeeping areas can increase the project's overall initial cost. Also, dedicated ventilation and exhaust systems may require additional ductwork and associated installation costs. However, effective cleaning spaces and systems coupled with good human health initiatives should prove economically sound over the lifetime of the building. Clean air can help support worker productivity, and this translates into increased profitability for the company. Reducing the potential for spills can avoid costly environmental cleanups.

### Community Issues

Good housekeeping benefits the community by reducing the potential for chemical spills that can impact neighboring properties. An environmentally sound building also supports the well-being of occupants, which may contribute to lowering health insurance rates and healthcare costs.

### Regional Issues

Local weather conditions should be factored into determining the location and type of entryway systems. For example, in areas that are prone to large amounts of rain or snow, it may be prudent to locate entryway systems in an enclosed vestibule or inside the building. A floor drain beneath the grille may also be necessary to remove collected moisture.

### Environmental Issues

Additional materials and energy may be required to provide entryway systems and isolated chemical use areas. This can increase natural resource consumption as well as air and water pollution. However, through proper management of hazardous chemicals used for building operations and maintenance, chemical spills and accidents can be avoided that would otherwise harm wildlife and ecosystems.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**Green Seal**

www.greenseal.org/recommendations.htm

(202) 872-6400

Green Seal is an independent nonprofit organization that promotes the manufacture and sale of environmentally responsible consumer products. This website contains product recommendations for general purpose cleaning solutions.

**Janitorial Products Pollution Prevention Project**

www.westp2net.org/janitorial/jp4.htm

A governmental and nonprofit project that researches issues and provides fact sheets, tools and links.

**EPA Environmentally Preferable Product Information**

www.epa.gov/opptintr/epp/

This website includes links to cleaning product information and a database of environmental information on over 600 products, including janitorial and pest control products.

### Print Media

*Clean and Green: The Complete Guide to Non-Toxic and Environmentally Safe Housekeeping* by Annie Berthold-Bond, Ceres Press, 1994.

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|
| Credit 6.1 | | | | | |

1 point

# Controllability of Systems

## Lighting

### Intent

Provide a high level of lighting system control by individual occupants or by specific groups in multi-occupant spaces (i.e., classrooms or conference areas) to promote the productivity, comfort and well-being of building occupants.

### Requirements

Provide individual lighting controls for 90% (minimum) of the building occupants to enable adjustments to suit individual task needs and preferences.

AND

Provide lighting system controllability for all shared multi-occupant spaces to enable lighting adjustment that meets group needs and preferences.

### Potential Technologies & Strategies

Design the building with occupant controls for lighting. Strategies to consider include lighting controls and task lighting. Integrate lighting systems controllability into the overall lighting design, providing ambient and task lighting while managing the overall energy use of the building.

## Summary of Referenced Standard

There is no standard referenced for this credit.

## Approach and Implementation

Conventional buildings too frequently only have fixed-intensity general lighting systems which illuminate indoor spaces without consideration of specific tasks and individual occupant comfort. A more desirable approach provides uniform general ambient lighting, augmented with individually controlled task fixtures.

During the early planning phase of a project, it is important to ask questions that will enable the design team to understand the client's lighting needs and desires. Determine the tasks that will be accomplished in each space and the specific tools and equipment that will be used by occupants. For example, a lighting strategy that is appropriate for a computer data entry area may not provide the functionality needed for other occupant functions. When developing a task-ambient approach, the designer should investigate methods for providing uniform ambient illumination. Increased uniformity will reduce the perception of decreased foot-candle levels in open spaces by minimizing high contrast areas. Designers should investigate the benefits of direct/indirect or pendant mounted systems coupled with high reflectance ceiling surfaces and finishes. Integration of surface materials selection and lighting design may create opportunities to reduce the number of installed lighting fixtures, resulting in potential energy savings.

To comply and be consistent with ANSI/ASHRAE/IESNA 90.1-2004, task lighting must be included in the lighting allowance for EA Prerequisite 2 and EA Credit 1.2. Daylighting can be integrated with this credit by using daylighting technologies and strategies to compensate for the reduced footcandle levels in the space, as detailed in EQ Credits 8.1 and 8.2. It is important to determine if any installed lighting systems or controls will require special calibration and commissioning prior to occupancy. The office and equipment layout should be carefully analyzed to ensure that 90% of the occupants have the lighting controls. Task lights come in several varieties, from desk-top lamps to fixtures that are permanently attached to workstations. While not required, designers should investigate the potential for the selected task lighting to have user-adjustable lighting levels and automatic shutoff switching.

It is important to remember that the operation of automatic occupancy sensors, daylight sensors, and other lighting controls may be adversely affected by items that are installed during and following construction, such as office equipment and furnishings. It is important to coordinate the final calibration of these items with the installer and commissioning agent early in the construction phase to ensure the system operates as design intended, providing lighting controls to 90% of the occupants.

## Calculations

### Adjustable Task Lighting

To satisfy this portion of the requirement, start by identifying those workstation locations intended for individual use. The total count should include private offices, open plan workstations, reception stations, ticket booths, etc. Confirm that 90% or more of these occupants have task lighting that enables adjustment to suit individual task needs. Adjustability, at a minimum, must allow the workstation occupant the ability to turn the fixture on and off. Ideally the fixture should be able to be easily repositioned by the occupant and should have multiple light levels.

The fixture should be appropriate for the occupant's task. In LEED-NC, task lights need not be permanently wired.

### Shared Multi-Occupant Spaces

These spaces include conference rooms, classrooms and other indoor spaces used as a place of congregation for functions such as presentations and training. In these spaces, the work group should have access to adequate controls to provide the functionality to suit their activities. Specific types or numbers of controls are not listed in the credit requirements to allow for flexibility in designing to the unique uses of each project. Meeting spaces that can be subdivided, as with a movable wall in a convention hall, must be designed so occupants in each area have control of their individual area. When daylighting is used as a component of an ambient lighting scheme, in either type of space, there should be glare control, lighting level controls and room-darkening shades (where required by function.)

## Exemplary Performance

This credit is not eligible for exemplary performance under the Innovation in Design section.

## Submittal Documentation

This credit is submitted as part of the **Design Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

- ❑ For individual workstation controls, provide a listing of the total number of individual workstations and lighting controls.
- ❑ For shared multi-occupant space control, provide a listing of the project's group multi-occupant spaces and a description of the installed lighting controls.
- ❑ Provide a narrative describing the project's lighting control strategy. Include data regarding the type and location of individual controls (general area illumination controls for multi-workstation spaces may not be counted towards this credit) and also the type and location of controls provided for shared multi-occupant spaces.

## Considerations

### Cost Issues

Additional task lights and lighting controls may increase first costs for the building. However, these costs are generally offset by reduced heat load and may allow designers to reduce ambient footcandle levels, thereby lowering the required amount of installed fixtures and lamps. Conversely, abuse of personal controls, such as leaving task lights on when not in the office, has the potential to increase energy costs. Therefore, it is important to educate occupants on the design and function of system controls. Integrating individual controls with occupancy sensors provides project teams with an opportunity to reduce the overall energy cost.

### Environmental Issues

Provision of individual controls for lighting can lead to increased occupant comfort by enabling occupants to tailor the workspace to their individual needs. Additionally, by reducing ambient space footcandle levels and providing user controlled, flexible, task-appropriate lighting, the project may reduce the overall lighting energy costs and reduce heat loads associated with high footcandle levels of indoor lighting.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**A Field Study of PEM (Personal Environmental Module) Performance in Bank of America's San Francisco Office Buildings**

www.cbe.berkeley.edu/research/pdf_files/bauman1998_bofa.pdf

This University of California, Berkeley Center for Environmental Design Research provides information on lighting quality, underfloor air distribution technologies and other topics.

**"Do Green Buildings Enhance the Well-being of Workers? Yes"**

***Environmental Design + Construction***

www.edcmag.com/CDA/ArticleInformation/coverstory/BNPCoverStoryItem/0,4118,19794,00.html

This article by Judith Heerwagen, PhD in the July/August 2000 edition of *Environmental Design + Construction*, quantifies the effects of green building environments on productivity.

### Print Media

*Controls and Automation for Facilities Managers: Applications Engineering* by Viktor Boed, CRC Press, 1998.

## Definitions

**Shared (Group) Multi-Occupant Spaces** include conference rooms, classrooms and other indoor spaces used as a place of congregation for presentations, trainings, etc. Individuals using these spaces share the lighting and temperature controls and they should have, at a minimum, a separate zone with accessible thermostat and an air-flow control.

**Individual Occupant Spaces** are typically private offices and open office plans with workstations.

**Non-Occupied Spaces** include all rooms used by maintenance personnel that are not open for use by occupants. Included in this category are janitorial, storage and equipment rooms, and closets.

**Non-Regularly Occupied Spaces** include corridors, hallways, lobbies, break rooms, copy rooms, storage rooms, kitchens, restrooms, stairwells, etc.

1 point

# Controllability of Systems

## Thermal Comfort

### Intent

Provide a high level of thermal comfort system control by individual occupants or by specific groups in multi-occupant spaces (i.e., classrooms or conference areas) to promote the productivity, comfort and well-being of building occupants.

### Requirements

Provide individual comfort controls for 50% (minimum) of the building occupants to enable adjustments to suit individual task needs and preferences. Operable windows can be used in lieu of comfort controls for occupants of areas that are 20 feet inside of and 10 feet to either side of the operable part of the window. The areas of operable window must meet the requirements of ASHRAE 62.1-2004, paragraph 5.1, Natural Ventilation.

AND

Provide comfort system controls for all shared multi-occupant spaces to enable adjustments to suit group needs and preferences.

Conditions for thermal comfort are described in ASHRAE Standard 55-2004 to include the primary factors of air temperature, radiant temperature, air speed and humidity. Comfort system control, for the purposes of this credit, is defined as the provision of control over at least one of these primary factors in the occupant's local environment.

### Potential Technologies & Strategies

Design the building and systems with comfort controls to allow adjustments to suit individual needs or those of groups in shared spaces. ASHRAE Standard 55-2004 identifies the factors of thermal comfort and a process for developing comfort criteria for building spaces that suit the needs of the occupants involved in their daily activities. Control strategies can be developed to expand on the comfort criteria to allow adjustments to suit individual needs and preferences. These may involve system designs incorporating operable windows, hybrid systems integrating operable windows and mechanical systems, or mechanical systems alone. Individual adjustments may involve individual thermostat controls, local diffusers at floor, desk or overhead levels, or control of individual radiant panels, or other means integrated into the overall building, thermal comfort systems, and energy systems design. In addition, designers should evaluate the closely tied interactions between thermal comfort (as required by ASHRAE Standard 55-2004) and acceptable indoor air quality (as required by ASHRAE Standard 62.1-2004, whether natural or mechanical ventilation).

## Summary of Referenced Standards

**ANSI/ASHRAE Standard 62.1-2004: Ventilation for Acceptable Indoor Air Quality**

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

www.ashrae.org

(800) 527-4723

Section 5.1 (Natural Ventilation) of the standard provides minimum requirements for operable openings. The portion of the window that can be opened must be 4% of the net occupiable floor area. The means to open the windows must be readily accessible to building occupants.

**ANSI/ASHRAE Standard 55-2004: Thermal Environmental Conditions for Human Occupancy**

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

www.ashrae.org

(800) 527-4723

ASHRAE Standard 55-2004 identifies the factors of thermal comfort and the process for developing comfort criteria for a building space and the occupants of that space. "This standard specifies the combinations of indoor space environment and personal factors that will produce thermal environmental conditions acceptable to 80% or more of the occupants within a space. The environmental factors addressed are temperature, thermal radiation, humidity, and air speed; the personal factors are those of activity and clothing." (ASHRAE)

## Approach and Implementation

Conventional buildings too frequently are built as sealed space where the occupants have no control. A more desirable approach provides individuals the controls to adjust the thermal conditions for a more comfortable environment. The components of an individual's thermal comfort include air temperature and velocity, the amount of outside air and moisture content.

The design team should determine the level of individual control desired. Design the building with comfort controls to suit both individual needs and those of groups in shared spaces.

Strategies to consider include designs with operable windows, hybrid designs incorporating operable windows and mechanical systems, or mechanical systems alone. Individual control of comfort with mechanical systems may be integrated into the overall systems design by enabling individual adjustment of selected comfort parameters, such as individual thermostats, individual diffusers (located at floor, desk or overhead), and individual radiant panels. Occupancy sensors can also be integrated in the design to automatically turn down the thermostat and reduce airflow when occupants are away, helping reduce energy use.

Occupants must be educated on individual control of their office space environment. Additionally, key maintenance staff must be trained in the operations of the HVAC equipment and any installed controls.

## Calculations

### Individual Thermal Comfort

To satisfy this portion of the requirement, start by identifying those workstation locations intended for individual use. The count should include private offices, open plan workstations, reception stations, ticket booths, etc. Confirm that 50% or more of individuals occupying these locations have at least one means of individual control over thermal comfort.

Operable windows may be used in lieu of individual controls for those occupants located within 20 ft. of the exterior wall and within 10 ft. of either side of the operable part of the window. The operable portion of the window will need to comply with the free-opening size criteria of ASHRAE Standard 62.1-2004 section 5.1. The minimum area of the window opening may be 4% of the net occupiable area for the ventilation purposes, however larger opening areas may be required for thermal comfort over a wide range of outside conditions. For the limits used in this credit, an area 20 ft. by 20 ft. per window, the opening size would need to be 16 sq.ft.

### Shared Multi-Occupant Spaces

To satisfy this portion of the requirement, start by identifying those areas where transient groups share spaces, such as conference rooms, break rooms and lecture halls. Specific types or numbers of controls are not listed in the credit requirements to allow for flexibility in designing to the unique uses of each project. Confirm that there is at least one means of control over thermal comfort that is accessible. Meeting spaces that can be subdivided, as with a movable wall in a convention hall, must be designed so occupants in each area have control of their individual area.

## Exemplary Performance

This credit is not eligible for exemplary performance under the Innovation in Design section.

## Submittal Documentation

This credit is submitted as part of the **Design Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

- ❑ For individual workstation controls, provide a listing of the total number of individual workstations and thermal controls.
- ❑ For shared multi-occupant space control, provide a listing of the project's group multi-occupant spaces and a description of the installed thermal controls.
- ❑ Provide a narrative describing the project's comfort control strategy. Include data regarding the type and location of individual and shared group-occupancy controls.

## Considerations

### Cost Issues

The most frequently reported occupant complaints involve thermal discomfort. Greater thermal comfort may increase occupant performance and attendance and, at least, will reduce complaints. According to the Rocky Mountain Institute's Green Developments in Real Estate, office worker salaries are estimated to be 72 times higher than energy costs, and they account for 92% of the life-cycle costs of a building; with this in mind, thermal comfort can have a tremendous effect on overall costs. As noted in a report published by the Center for the Built Environment ("Giving Occupants What They Want: Guidelines for Implementing Personal Environmental Control in Your Building" by Fred S. Bauman, PE – 1999) studies have shown that individual occupant controls can potentially increase the satisfaction and productivity of occupants. The financial implications of such improvements can be extremely large for building owners. Additional controllability may add to first costs of a project, however, these costs are generally offset by energy savings through lower conditioned temperatures, natural ventilation and less solar gain through proper use of shading devices. Conversely, abuse of personal controls such as setting thermostats too high or leaving windows open during non-working hours increases energy costs. Therefore, it is important to educate occupants on the design and function of system controls.

Alteration of the ventilation and temperature scheme may change the energy performance of the building and may require commissioning and Measurement & Verification attention. Controllability of systems may not be possible for occupants in existing buildings being rehabilitated, especially with regard to operable windows. The degree of occupant controls will affect the performance of the ventilation system. Daylighting and view strategies are affected by the controlling requirements of the operable windows in this credit.

### Regional Issues

Local weather and ambient air conditions must be considered when determining the feasibility of operable windows for projects. For example, in areas that are prone to extreme temperatures for a majority of the year, or urban areas where traffic and air pollution are problematic, operable windows may not be an appropriate addition to a building.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**Center for the Built Environment**

www.cbe.berkeley.edu

This University of California, Berkeley Center for Environmental Design Research provides information on underfloor air distribution technologies and other topics. See the publications page for articles such as "A Field Study of PEM (Personal Environmental Module) Performance in Bank of America's San Francisco Office Buildings."

**"Do Green Buildings Enhance the Well-being of Workers? Yes"**

***Environmental Design + Construction***

www.edcmag.com/CDA/ArticleInformation/coverstory/BNPCoverStoryItem/0,4118,19794,00.html

An article by Judith Heerwagen in the July/August 2000 edition, of *Environmental Design + Construction* quantifies the effects of green building environments on productivity.

### Print Media

*Controls and Automation for Facilities Managers: Applications Engineering* by Viktor Boed, CRC Press, 1998.

*Giving Occupants What They Want: Guidelines for Implementing Personal Environmental Control in Your Building* by Fred S. Bauman, PE, Center for the Built Environment, 1999.

*Using advanced office technology to increase productivity: the impact of environmentally responsive workstations (ERWs) on productivity and worker attitude* by W. Kroner, J. Stark-Martin, and T. Willemain. 1992. The Center for Architectural Research, Rensselaer Polytechnic Institute, Troy, N.Y.

## Definitions

**Shared (Group) Multi-Occupant Spaces** include conference rooms, classrooms and other indoor spaces used as a place of congregation for presentations, trainings, etc.

**Individual Occupant Spaces** are typically private offices and open office plans with workstations.

**Non-Occupied Spaces** include all rooms used by maintenance personnel that are not open for use by occupants. Included in this category are janitorial, storage and equipment rooms, and closets.

**Non-Regularly Occupied Spaces** include corridors, hallways, lobbies, break rooms, copy rooms, storage rooms, kitchens, restrooms, stairwells, etc.

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|

Credit 7.1

1 point

EB

# Thermal Comfort

## Design

### Intent

Provide a comfortable thermal environment that supports the productivity and well-being of building occupants.

### Requirements

Design HVAC systems and the building envelope to meet the requirements of ASHRAE Standard 55-2004, Thermal Comfort Conditions for Human Occupancy. Demonstrate design compliance in accordance with the Section 6.1.1 Documentation.

### Potential Technologies & Strategies

Establish comfort criteria per ASHRAE Standard 55-2004 that support the desired quality and occupant satisfaction with building performance. Design building envelope and systems with the capability to deliver performance to the comfort criteria under expected environmental and use conditions. Evaluate air temperature, radiant temperature, air speed, and relative humidity in an integrated fashion and coordinate these criteria with EQ Prerequisite 1, EQ Credit 1 and EQ Credit 2.

## Summary of Referenced Standards

**ASHRAE Standard 55-2004, Thermal Comfort Conditions for Human Occupancy**

American Society of Heating, Refrigerating and Air-Conditioning Engineers

"This standard specifies the combinations of indoor space environment and personal factors that will produce thermal environmental conditions acceptable to 80% or more of the occupants within a space. The environmental factors addressed are temperature, thermal radiation, humidity, and air speed; the personal factors are those of activity and clothing." (ASHRAE)

## Approach and Implementation

If properly designed, built, and operated, a green building provides its occupants with comfortable indoor conditions that support their productivity and well-being. Although often associated only with air temperature, thermal comfort is a complex issue, impacted by environmental conditions (air temperature, radiant temperature, humidity and air speed) and personal factors (metabolic rate and clothing level) as well as personal preferences of occupants.

## Strategies

There are three basic approaches to providing thermal comfort within a project space:

- ❑ Active Conditioning (e.g. mechanical HVAC systems)
- ❑ Passive Conditioning (e.g. natural ventilation)
- ❑ Mixed-mode conditioning—employing a combination of active and passive systems

The owner and project team should make a decision as to which of the conditioning approaches are appropriate for the building. ASHRAE Standard 55-2004 provides thermal comfort standards, with an optional alternate approach specifically for naturally ventilated spaces.

ASHRAE 55-2004 is based on the Predicted Mean Vote (PMV) comfort model which incorporates heat balance principles to relate the personal and environmental thermal comfort factors based on the thermal sensation scale that shows seven levels ranging from +3 (hot) to -3 (cold). The PMV model is applicable to air speeds not greater than 0.20 m/s (40 fpm).

For naturally ventilated spaces, the standard notes that field experiments have shown that occupants' thermal responses depend in part on the outdoor climate and may differ from thermal responses in buildings with centralized HVAC systems. This is primarily because of the different thermal experiences, changes in clothing, availability of control, and shifts in occupant expectations. The standard provides an optional method of compliance, intended for naturally ventilated spaces. This optional method (section 5.3 of the standard) provides broad indoor temperature ranges as a function of mean monthly outdoor temperatures; assuming light, sedentary activity but independent of humidity, air speed and clothing considerations.

### Planning & Design Phase

Using ASHRAE Standard 55-2004, the design team and the owner in collaboration should identify the environmental parameters required to maintain the desired thermal comfort in the project space and then identify the conditioning systems (whether active or passive) that can best provide these conditions. This decision may be influenced by the size, type, location, and climatic conditions of the proposed building as well as the nature of the operations that will occur in the building.

There are many well established HVAC load calculation methodologies to assist designers in sizing and selecting HVAC equipment in order to provide thermal comfort conditions. Lighting systems and other internal HVAC loads are integrated into the HVAC sizing calculations, to allow for adequate system capacity to meet thermal comfort criteria without over-sizing the HVAC systems.

A natural ventilation approach may be more difficult to evaluate in design and require more intensive analysis and/or reliance on experience and precedents. For naturally ventilated buildings CIBSE AM10 presents design strategies for comfortable and healthy naturally ventilated buildings.

### Operation Phase

For mechanical conditioning, the operating setpoints and parameters of the HVAC system will be a primary influence on thermal comfort conditions in the project space. Many facility operators in mechanically air-conditioned spaces spend significant effort and time adjusting thermostat setpoints and other operational parameters in order to limit complaints associated with poor thermal comfort. Systems where individual occupants are provided some amount of direct control over temperature and/or air movement generally yield fewer thermal comfort complaints.

The maxim “passive buildings, active occupants” fits the natural ventilation model well. Occupants generally take a primary role in managing thermal comfort conditions in naturally ventilated buildings by opening and closing windows as necessary and appropriate. Thermal comfort in naturally conditioned buildings is also somewhat more variable and tied to the ambient conditions than in mechanically conditioned buildings where systems are often designed to maintain relatively consistent conditions through all periods of occupancy.

## Calculations

There are no calculations required for this LEED-NC credit. However, project teams should be able to describe how thermal comfort conditions were established for the project and how the design of conditioning systems addresses the thermal comfort design criteria.

## Exemplary Performance

This credit is not eligible for exemplary performance under the Innovation in Design section.

## Submittal Documentation

This credit is submitted as part of the **Design Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

- ❑ Provide data regarding seasonal temperature and humidity design criteria.
- ❑ Provide a narrative describing the method used to establish the thermal comfort conditions for the project and how the systems design addresses the design criteria. Include specific information regarding compliance with the referenced standard.

## Considerations

### Environmental Issues

Building conditioning systems, including both active HVAC systems and natural ventilation systems, are designed and installed in buildings to enhance thermal comfort for building occupants. These building conditioning systems may serve other functions as well, including providing ventilation air and providing thermal conditioning for equipment and processes. Designing and installing building conditioning systems to provide superior thermal comfort, ventilation, and indoor air quality as efficiently, and cost effectively as possible is a central challenge for many green building projects

### Synergies and Trade-Offs

An active HVAC system generally will provide a higher degree of control over indoor thermal comfort conditions than a passive conditioning system. Capital, energy and lifecycle costs, however, are generally higher for an active HVAC system than for a naturally ventilated system.

Natural ventilation and other passive conditioning approaches are often dependent on occupants' managing the system (e.g. opening windows or closing blinds at appropriate times) to meet the comfort criteria. Active conditioning systems generally rely on central automation systems to comply with little or no direct occupant control.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**Enhance Indoor Environmental Quality (IEQ), The Whole Building Design Guide**

www.wbdg.org/design/ieq.php

The Indoor Environmental Quality section provides a wealth of resources including definitions, fundamentals, materials and tools.

### Print Media

ASHRAE Standard 62.1 –2004: Ventilation for Acceptable Indoor Air Quality, ASHRAE, 2004.

*Humidity Control Design Guide* by L. Harriman, G.W. Brundett and R. Kittler, ASHRAE, 2000.

*The Impact of Part-Load Air-Conditioner Operation on Dehumidification Performance: Thermal Comfort* by P.O. Fanger, Mc-Graw Hill, 1973.

*Thermal Delight in Architecture* by Lisa Heschong, MIT Press, 1979.

## Definitions

**Natural Ventilation** is the ventilation provided by thermal, wind, or diffusion effects through doors, windows, or other intentional openings in the building. (ASHRAE 62.1-2004)

**Relative Humidity** is the ratio of partial density of water vapor in the air to the saturation density of water vapor at the same temperature and the same total pressure. (ASHRAE 55-2004).

**Thermal Comfort** is a condition of mind experienced by building occupants expressing satisfaction with the thermal environment.

**Comfort Criteria** is specific original design conditions that shall at minimum include temperature (air, radiant and surface), humidity and air speed as well as outdoor temperature design conditions, outdoor humidity design conditions, clothing (seasonal) and activity expected. (ASHRAE 55-2004)

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|

Credit 7.2

1 point

EB

# Thermal Comfort

## Verification

### Intent

Provide for the assessment of building thermal comfort over time.

### Requirements

Agree to implement a thermal comfort survey of building occupants within a period of six to 18 months after occupancy. This survey should collect anonymous responses about thermal comfort in the building including an assessment of overall satisfaction with thermal performance and identification of thermal comfort-related problems. Agree to develop a plan for corrective action if the survey results indicate that more than 20% of occupants are dissatisfied with thermal comfort in the building. This plan should include measurement of relevant environmental variables in problem areas in accordance with ASHRAE Standard 55-2004.

### Potential Technologies & Strategies

ASHRAE Standard 55-2004 provides guidance for establishing thermal comfort criteria and the documentation and validation of building performance to the criteria. While the standard is not intended for purposes of continuous monitoring and maintenance of the thermal environment, the principles expressed in the standard provide a basis for design of monitoring and corrective action systems.

## Summary of Referenced Standards

**ASHRAE Standard 55-2004, Thermal Comfort Conditions for Human Occupancy**

American Society of Heating, Refrigerating and Air-Conditioning Engineers

"This standard specifies the combinations of indoor space environment and personal factors that will produce thermal environmental conditions acceptable to 80% or more of the occupants within a space. The environmental factors addressed are temperature, thermal radiation, humidity, and air speed; the personal factors are those of activity and clothing." (ASHRAE)

## Approach and Implementation

When properly designed, built and operated, a green building provides its occupants with comfortable indoor conditions that support their productivity and well-being. Since poor thermal comfort is the primary occupant complaint in many facilities, a well managed and responsive green building should have systems in place to gauge whether occupant comfort is being maintained or can be improved.

## Strategies

Since thermal comfort is inherently subjective and is psychological as much as physiological, regularly surveying occupants may be the best way to determine if a facility is "comfortable." Sporadic occupant complaints about thermal comfort may not be an appropriate indicator of overall thermal comfort but rather an indicator of local or personal dissatisfaction. Providing a systematic process and mechanism for all occupants to provide feedback about their thermal comfort will help building operators adjust and maintain thermal comfort in the building.

Temperature, humidity and other environmental monitoring systems provide facility operators with objective data to determine if the building space conditions meet the design intent and/or if they are being maintained consistently through the occupied periods.

### Planning & Design Phase

Once the project has identified appropriate thermal comfort criteria (as part of compliance with EQ Credit 7.1) and determined the appropriate conditioning system to meet the criteria, the project team should identify the key areas of focus for the occupant survey and should anticipate provisions for analysis of environmental variables should the survey identify problems.

### Survey Occupants

Facility operators or outside consultants shall develop procedures to survey building occupants about thermal comfort conditions. The main parameter to be measured in the occupant survey is satisfaction with thermal environment (e.g.: "How satisfied are you with the temperature in your workspace?"). The answer is posed in a seven-point scale format running from very satisfied (+3) to very dissatisfied (-3) with the center (0) signifying the neutral point. Survey respondents identify their approximate location by building nominal zone, and can specify their exact location voluntarily. The survey must include follow-up questions that are asked if the respondent indicates dissatisfaction, to identify the nature and cause of the problem. Sources of sample surveys include, but are not limited to, the Center for the Built Environment and the Usable Buildings Trust (see Resources below.)

This survey may be administered in person, over the phone, over networked computers, or on paper but should be consistently applied and available for participation by all regular occupants.

Percent dissatisfied will be the percentage of respondents who answer “dissatisfied” (any of the lower three point of the seven-point scale, i.e., <0) on the satisfaction with the thermal environment question.

The survey may encompass other indoor environmental quality considerations (such as lighting or acoustics) as well, although this is not required for this LEED-NC credit.

### Plan for Corrective Action

The survey will identify the nature and location of any thermal environmental problems and the diagnostic questions will suggest directions for corrective actions. Corrective actions typically include: control adjustments (e.g., temperature setpoints, schedules, operating modes), diffuser airflow adjustments, and solar control.

Thermal discomfort in buildings is often caused by local variations in the thermal environment. It is impractical to have thermal comfort monitoring systems in every workstation in the building that are capable of monitoring and diagnosing thermal comfort problems. The resolution of performance failure is at the discretion of the design team and facility O&M staff. Short-term monitoring and spot measurements of environmental variables with temporary equipment should be done once problem areas have been identified through the occupant survey.

## Calculations

There are no calculations associated with this credit.

## Exemplary Performance

This credit is not eligible for exemplary performance under the Innovation in Design section.

## Submittal Documentation

This credit is submitted as part of the **Design Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

- ❑ Provide a narrative describing the survey planned for the validation of the thermal comfort conditions for the project. Include a specific description of the provisions for creating a plan for corrective action.

## Considerations

### Cost Issues

Monitoring, managing and maintaining thermal comfort conditions in a building may increase or decrease building operating costs slightly. Thermal comfort complaints are among the most prevalent occupant complaints in many buildings. Maintaining thermal comfort in a building may allow operations and maintenance staff to address other facility issues more thoroughly by reducing the need to respond to “hot calls” and “cold calls.”

### Synergies and Trade-Offs

Thermal comfort monitoring (via occupant surveying or monitoring environmental variables) may add capital, operations and/or maintenance costs to a facility. The building systems, building use, and occupants may change with time, requiring on-going maintenance and perhaps adjustments to thermal comfort systems. Reducing thermal comfort problems and complaints contributes to occupant well-being and may allow facility operations and maintenance staff to focus on other critical areas.

### Environmental Issues

For many facilities, the HVAC systems which maintain indoor thermal comfort are the largest energy end-use. A successful green building should minimize the energy use associated with building conditioning—along with the associated energy cost, fuel consumption and air emissions—while maintaining thermal comfort conditions that enhance the occupants' well-being.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**Center for the Built Environment (CBE)**

www.cbesurvey.org

An introduction to Center for the Built Environment (CBE) web-based indoor environmental quality survey.

**The Usable Buildings Trust**

www.usablebuildings.co.uk/

The Usable Buildings Trust promotes better buildings through the more effective use of feedback. Home of the PROBE studies includes an occupant survey that addresses thermal comfort along with other indoor environmental quality issues.

### Print Media

"Unplanned Airflows and Moisture Problems" by T. Brennan, J. Cummings and J. Lstiburek, *ASHRAE Journal*, November, 2000.

Federal Facilities Council, Technical Report 145: "Learning From our Buildings: a State-of-the-Practice Summary of Post-occupancy Evaluation," Washington, National Academy Press, 2001.

## Definitions

**Natural Ventilation** is the ventilation provided by thermal, wind or diffusion effects through doors, windows, or other intentional openings in the building. (ASHRAE 62.1-2004)

**Relative Humidity** is the ratio of partial density of water vapor in the air to the saturation density of water vapor at the same temperature and the same total pressure. (ASHRAE 55-2004)

**Thermal Comfort** is a condition of mind experienced by building occupants expressing satisfaction with the thermal environment.

**Comfort Criteria** is specific original design conditions that shall at minimum include temperature (air, radiant and surface), humidity and air speed as well as outdoor temperature design conditions, outdoor humidity design conditions, clothing (seasonal) and activity expected. (ASHRAE 55-2004)

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|

Credit 8.1

1 point

EB

# Daylight and Views

## Daylight 75% of Spaces

### Intent

Provide for the building occupants a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.

### Requirements

OPTION 1 — GLAZING FACTOR CALCULATION

Achieve a minimum glazing factor of 2% in a minimum of 75% of all regularly occupied areas. The glazing factor is calculated as follows:

$$\text{Glazing Factor} = \frac{\text{Window Area [SF]}}{\text{Floor Area [SF]}} \times \text{Window Geometry Factor} \times \frac{\text{Actual } T_{vis}}{\text{Minimum } T_{vis}} \times \text{Window Height Factor}$$

OR

OPTION 2 — DAYLIGHT SIMULATION MODEL

Demonstrate, through computer simulation, that a minimum daylight illumination level of 25 footcandles has been achieved in a minimum of 75% of all regularly occupied areas. Modeling must demonstrate 25 horizontal footcandles under clear sky conditions, at noon, on the equinox, at 30” above the floor.

OR

OPTION 3 — DAYLIGHT MEASUREMENT

Demonstrate, through records of indoor light measurements, that a minimum daylight illumination level of 25 footcandles has been achieved in at least 75% of all regularly occupied areas. Measurements must be taken on a 10-foot grid for all occupied spaces and must be recorded on building floor plans.

In all cases, only the square footage associated with the portions of rooms or spaces meeting the minimum illumination requirements can be applied towards the 75% of total area calculation required to qualify for this credit.

In all cases, provide daylight redirection and/or glare control devices to avoid high-contrast situations that could impede visual tasks. Exceptions for areas where tasks would be hindered by the use of daylight will be considered on their merits.

### Potential Technologies & Strategies

Design the building to maximize interior daylighting. Strategies to consider include building orientation, shallow floor plates, increased building perimeter, exterior and interior permanent shading devices, high performance glazing and automatic photocell-based controls. Predict daylight factors via manual calculations or model daylighting strategies with a physical or computer model to assess footcandle levels and daylight factors achieved.

## Summary of Referenced Standard

There is no standard referenced for this credit.

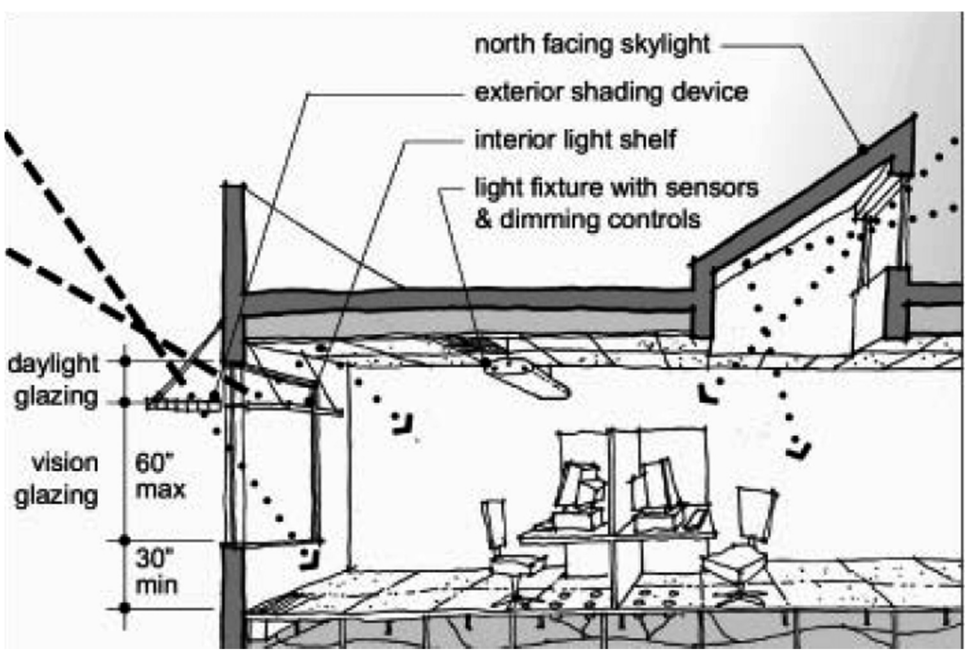
## Approach and Implementation

A building may have limited daylighting potential due to site or program constraints that limit the orientation of the building, number and size of building openings and floor plate dimensions. Vertical site elements such as neighboring buildings and trees may reduce the potential for daylighting. Evaluate the impact of the building's orientation on possible daylighting options; strive to incorporate shallow floor plates, courtyards, atriums, clerestory windows and skylights into the project to increase daylighting potential. Evaluate the potential to add interior light shelves, exterior fins, louvers and adjustable blinds. See **Figure 1**, which illustrates various daylighting strategies. Glazing parameters directly affect the heat gain and loss of the building which may result in increased energy use. It is important to address the glazing properly not only for energy usage but also for visual quality.

The desired amount of daylight will differ depending on the tasks occurring within each program space. Daylit spaces often have several daylight zones with differing target light levels. In addition to light levels, daylighting strategies should address interior color schemes, direct beam penetration and integration with the electric lighting system. Glare control is perhaps the most common failure in daylighting strategies. Glare is defined as any excessively bright source of light within the visual field that creates discomfort or loss in visibility. Large window areas provide generous amounts of daylight to the task area. If not controlled properly, this daylight can produce unwanted glare and affect the lighting quality. Measures to control glare include light shelves, louvers, blinds, fins and shades. Typically, low luminance ratios and lighting of primary surfaces will enhance visual quality.

Computer modeling software can be used to simulate daylighting conditions and to provide valuable input into the

**Figure 1:** An illustration of Various Daylighting Strategies



development of an effective, integrated daylighting strategy. Daylighting software produces continuous daylight contours to simulate the daylighting conditions of interior spaces and to account for combined effects of multiple windows within a daylit space.

Photo-responsive controls for electric lighting can be incorporated into daylighting strategies to maintain consistent light levels and to minimize occupant perception of the transition from natural light to artificial light. These controls result in energy savings by reducing electric lighting in high daylight conditions while preserving footcandle levels on the task surface. These types of automatic controls require commissioning and also Measurement & Verification attention.

## Calculations

Compliance with the requirements for this credit may be determined by either following the Glazing Factor calculation methodology (outlined in the following paragraphs) to determine overall glazing factor, or by using daylighting simulation software to determine point-by-point illumination levels (footcandles) measured at desk height (30" above the finished floor).

Areas to include in the daylighting calculations are all regularly occupied spaces such as office spaces, meeting areas and cafeterias. Areas that should not be considered include support areas for copying, storage, mechanical equipment, laundry and restrooms.

The calculation methodology below can be applied to approximate the Glazing Factor for each regularly occupied room in the building. The Glazing Factor (GF) is the ratio of exterior illumination to interior illumination and is expressed as a percentage. The variables used to determine the daylight factor include the floor area, window area, window geometry, visible transmittance ($T_{vis}$) and window height. This calculation method aims to provide a minimum 2% GF at the back of a space. The Glazing Factor calculation method is designed to identify daylighting conditions based on room and window geometry and visible transmittance based on meeting the performance criteria for overcast sky conditions. Currently this calculation method doesn't take into account light shelves, partitions, significant exterior obstructions or exterior reflective surfaces.

The development of a Daylight Simulation Model is highly recommended where daylighting strategies go beyond the current capability to the Glazing Factor Calculation Method.

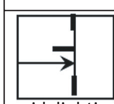
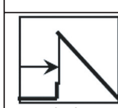
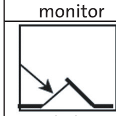
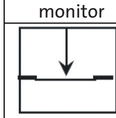
### Option 1—Glazing Factor

1. Create a spreadsheet and identify all regularly occupied rooms/areas. Determine the floor area of each applicable room using construction documents.
2. For each room/area identified, calculate the window area and use **Table 1** to indicate the acceptable window types. Note that window areas above 7'6" are considered to be daylight glazing. Glazing at this height is the most effective at distributing daylight deep into the interior space. Window areas from 2'6" to 7'6" are considered to be vision glazing. These window areas are primarily used for viewing and lighting interior spaces close to the building perimeter. Window areas below 2'6" do not contribute to daylighting of interior spaces and are to be excluded from the calculations.
3. For each window type, insert the appropriate geometry and height factors as listed in **Table 1**. The geometry factor indicates the effectiveness of a particular aperture to distribute daylight relative to window location. The height factor accounts for where light is introduced to the space.

4. For each window type, indicate the visible transmittance ($T_{vis}$), a variable number that differs for each product. Minimum $T_{vis}$ is the recommended level of transmittance for selected glazing.
5. Calculate the Glazing Factor for each window type using **Equation 1**. For rooms/areas with more than one window type, sum all window types to obtain a total Glazing Factor for the room/area.
6. If the total Glazing Factor for a room/area is 2% or greater, then the square footage of the room/area is applicable to the credit.
7. Sum the square footage of all applicable rooms/areas and divide by the total square footage of all regularly occupied spaces. If this percentage is equal to or greater than 75%, then the project qualifies for this point. (See **Note 1** below for further information.)
8. Note that glare control is also required for each window. **Table 3** provides best-practice glare control measures for different window types.

**Table 2** provides an example of daylighting calculations for a typical office space. All of the offices are considered to be regularly occupied spaces, while support areas such as hallways, foyers, storage

**Table 1:** Daylighting Design Criteria

| Window Type | Geometry Factor | Minimum $T_{vis}$ | Height Factor | Best Practice Glare Control |
|---|---|---|---|---|
|  sidelighting daylight glazing | 0.1 | 0.7 | 1.4 | Adjustable blinds<br>Interior light shelves<br>Fixed transluscent exterior shading devices |
|  sidelighting vision glazing | 0.1 | 0.4 | 0.8 | Adjustable blinds<br>Exterior shading devices |
|  toplighting vertical monitor | 0.2 | 0.4 | 1.0 | Fixed interior<br>Adjustable exterior blinds |
|  toplighting sawtooth monitor | 0.33 | 0.4 | 1.0 | Fixed interior<br>Exterior louvers |
|  toplighting horizontal skylights | 0.5 | 0.4 | 1.0 | Interior fins<br>Exterior fins<br>Louvers |

**Equation 1:** Glazing Factor Calculation

$$\text{Glazing Factor} = \frac{\text{Window Area [SF]}}{\text{Floor Area [SF]}} \times \text{Window Geometry} \times \frac{\text{Actual } T_{vis}}{\text{Minimum } T_{vis}} \times \text{Window Height Factor}$$

areas, mechanical rooms and restrooms are not considered to be regularly occupied. The example qualifies for this credit because it exceeds the minimum square footage percentage for daylit area and includes glare control on all windows in daylit rooms.

## Option 2—Daylight Simulation Model

1. Create a daylight simulation model for the building, or each regularly occupied space with glazing. The model should include appropriate glazing factors as well as representative surface reflectance settings for interior finishes.
2. For each applicable room/area, include a horizontal calculation grid at 30" above the floor. This grid will represent the typical work plane height. The calculation grid should be set at approximately 2 foot intervals to provide a detailed illumination diagram for each area. (For larger areas, it may be necessary to increase the grid size for clarity.)

**Table 3:** Common Glare Control Strategies

| Description |
|---|
| Fixed Exterior Shading Devices |
| Light Shelf, Exterior |
| Light Shelf, Interior |
| Interior Blinds or Pull-Down Shade |
| Fritted Glazing |
| Drapes |
| Electronic Black-Out Glazing |

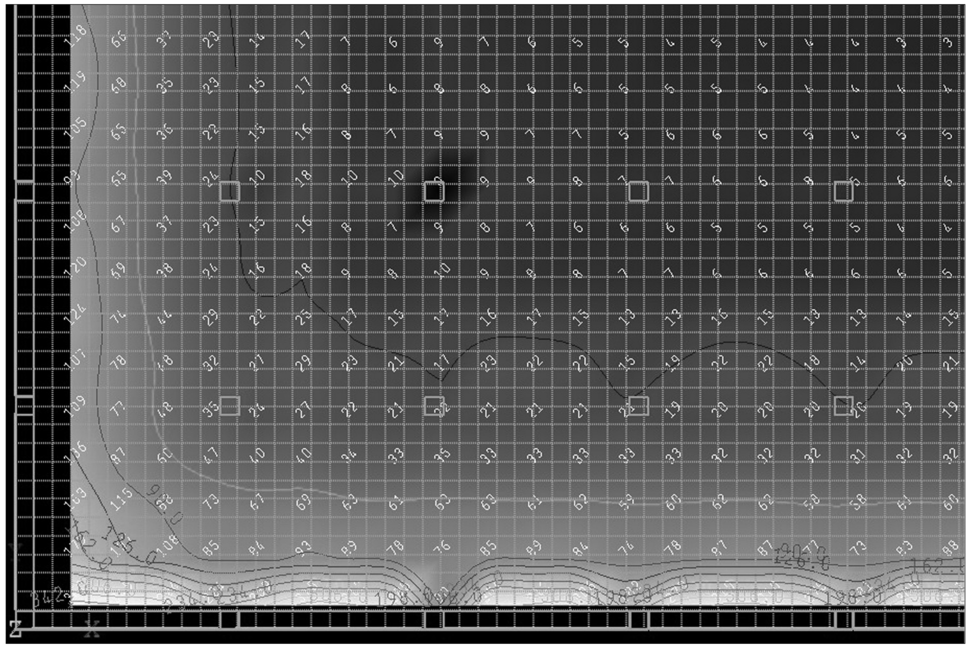
3. Calculate the daylight illumination for each applicable space using the following daylight criteria: clear sky conditions at 12:00 noon on the equinox (March 21/September 21) for the project's specific geographic location. **Figure 2** illustrates a sample daylight analysis for an office space.
4. Create a spreadsheet and identify all regularly occupied rooms/areas. Determine the floor area of each applicable room using construction documents. Provide the minimum illumination level (footcandles), determined through the simulation model, for each space.
5. If the minimum illumination for a room/area is 25 footcandles or greater,

**Table 2:** [LB3] Glazing Factor Tabulation Spreadsheet

| Regularly Occupied Space ID | Regularly Occupied Space Name | Regularly Occupied Space Area (sf) | Sidelighting - Vision Glazing | | Sidelighting - Daylight Glazing | | Toplighting Sawtooth Monitor | | Toplighting Vertical Monitor | | Toplighting Horizontal Skylight | | Glazing Factor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Area (sf) | $T_{vis}$ | Area (sf) | $T_{vis}$ | Area (sf) | $T_{vis}$ | Area (sf) | $T_{vis}$ | Area (sf) | $T_{vis}$ | |
| 101 | Office | 820 | 120 | 0.9 | 40 | 0.7 | 0 | N/A | 0 | N/A | 0 | N/A | 3.3 |
| 102 | Office | 330 | 30 | 0.9 | 5 | 0.7 | 0 | N/A | 0 | N/A | 0 | N/A | 1.8 |
| 103 | Open Office (Daylit Area) | 2250 | 330 | 0.9 | 110 | 0.7 | 0 | N/A | 0 | N/A | 0 | N/A | 3.3 |
| 103 | Open Office (Non-Daylit Area) | 685 | 0 | 0.9 | 0 | 0.7 | 0 | N/A | 0 | N/A | 0 | N/A | 0 |
| 104 | Office | 250 | 25 | 0.9 | 5 | 0.7 | 0 | N/A | 0 | N/A | 0 | N/A | 2.1 |
| 105 | Office | 250 | 25 | 0.9 | 5 | 0.7 | 0 | N/A | 0 | N/A | 0 | N/A | 2.1 |

| Total Regularly Occupied Space Area (sf) | Total Regularly Occupied Space Area with a Minimum 2% Glazing Factor | Percentage of Regularly Occupied Space with a 2% Glazing |
|---|---|---|
| 4585 | 3570 | 78% |

**Figure 2:** Sample Daylight Simulation Model Output



then the square footage of the room/area is applicable to the credit. (See **Note 1** below for further information)

6. Sum the square footage of all daylit rooms/areas and divide by the total square footage of all regularly occupied spaces. If this percentage is equal to or greater than 75%, then the project qualifies for one point under this Credit.
7. Note that glare control is also required for each window. **Table 1** provides best-practice glare control measures for different window types. Create another spreadsheet entry that identifies the type of glare control applied to each window type. The type of glare control selected for each window does not affect the daylight factor calculations. **Table 3** provides a listing of common glare control strategies.

### Option 3—Daylight Measurement

**NOTE 1:** This credit can be approached so that 100% of each room does not have to meet the 2% daylight factor or the minimum 25 footcandle requirement. In order to do so, the portion of the room with a 2% (or higher) daylight factor or 25 footcandle minimum illumination would count towards the percentage of all space occupied for critical visual tasks. The portion of the room not meeting the daylight factor or illumination criteria would not count towards the compliant area total, but would be considered in the calculation of total area calculation. For the calculation spreadsheet, the two portions of the room (the one meeting the minimum daylight factor or illumination and the one not meeting the requirements) would be counted as separate spaces (See **Table 2**—Room 103 "Open Office"). The square footage of all compliant spaces is tallied and then divided over the total square footage of all regularly occupied spaces. If the percentage is equal to or greater than 75%, then the project qualifies for one point under this Credit.

## Exemplary Performance

This credit may be eligible for exemplary performance under the Innovation & Design section if the project achieves 95% daylighting based on the requirements and guidelines of this credit.

## Submittal Documentation

This credit is submitted as part of the **Design Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

**Glazing Factor Calculation Method**

- ❑ Complete the template calculation spreadsheet to demonstrate overall Glazing Factor. The following data is required for input in the template: occupied space area (sq.ft.); area of each type of glazing (sidelighting and toplighting); visible light transmittance ($T_{vis}$) for each glazing type.

OR

**Computer Simulation Method**

- ❑ Complete the template calculation spreadsheet to demonstrate that the project complies with the minimum illumination levels. The following data is required for input in the template: total regularly occupied space area (sq. ft.); total regularly occupied space area that achieves a simulated minimum of 25 footcandles.
- ❑ Provide copies of the applicable project drawings showing the illumination simulation results.

OR

**Daylight Measurement Method**

- ❑ Complete the template calculation spreadsheet to demonstrate that the project complies with the minimum illumination levels. The following data is required for input in the template: total regularly occupied space area (sq. ft.); total regularly occupied space area that achieves a measured minimum of 25 footcandles.
- ❑ Provide copies of the applicable project drawings showing the illumination simulation results.

AND

- ❑ Provide a narrative describing any special occupancy areas that have been excluded from compliance. The narrative should include a detailed description of the space function and an explanation as to why the inclusion of views would hinder the normal tasks/function of each excluded area.

  For projects that have used computer simulation or physical measurements, please include detailed information describing the method used to determine the daylighting contributions in the building. Include specific information regarding the actual or simulated time of day and weather conditions, measurement equipment or software used, and the calculation method for determining the final daylighting area.

## Considerations

### Cost Issues

Specialized glazing can increase initial costs for a project and can lead to excessive heat gain if not designed properly. Glazing provides less insulating effects compared to standard walls, resulting in higher energy use and requiring additional maintenance. However, offices with sufficient natural daylight have proven to increase occupant productivity and comfort. In most cases, occupant salaries significantly outweigh first costs of incorporating daylighting measures into a building design. Studies of schools and stores have shown that daylighting can improve student performance and retail sales (see the Resources section). Daylighting can significantly reduce artificial lighting requirements and energy costs in many commercial and industrial buildings, as well as schools, libraries and hospitals. Daylighting, combined with energy-efficient lighting and electronic ballasts, can reduce the lighting power density in some office buildings by up to 30%.

### Environmental Issues

Daylighting reduces the need for electric lighting of building interiors, resulting in decreased energy use. A well-designed daylit building is estimated to reduce lighting energy use by 50 to 80% (Sustainable Building Technical Manual, chapter IV.7, page 90). This conserves natural resources and reduces air pollution impacts due to energy production and consumption.

Daylighting design involves a careful balance of heat gain and loss, glare control, visual quality and variations in daylight availability. Shading devices, light shelves, courtyards, atriums and window glazing are all strategies employed in daylighting design. Important considerations include the selected building's orientation, window size and spacing, glass selection, reflectance of interior finishes and locations of interior walls. Daylit spaces also increase occupant productivity and reduce absenteeism and illness.

### Community Issues

Daylighting and outdoor views provide a connection with the building site and adjacent sites, creating a more integrated neighborhood. Daylit spaces can increase occupant productivity and reduce illness and absenteeism.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**Analysis of the Performance of Students in Daylit Schools**

www.innovativedesign.net/studentperformance.htm

Nicklas and Bailey's 1996 study of three daylit schools in North Carolina.

**The Art of Daylighting**

www.edcmag.com/CDA/ArticleInformation/features/BNP__Features__Item/0,4120,18800,00.html

This Environmental Design + Construction article provides a solid introduction to daylighting.

**New Buildings Institute's Productivity and Building Science Program**

www.newbuildings.org/downloads/FinalAttachments/PIER_Final_Report(P500-03-082).pdf

Provides case studies and report on the benefits of daylighting.

**Radiance Software**

http://radsite.lbl.gov/radiance/

Free daylighting simulation software from the Lawrence Berkeley National Laboratory

**The Whole Building Design Guide, Daylighting**

www.wbdg.org/design/daylighting.php?r=ieq

**Lighting Controls**

www.wbdg.org/design/electriclighting.php?r=ieq

The Daylighting and Lighting Controls sections provide a wealth of resources including definitions, fundamentals, materials and tools.

### Print Media

*Architectural Lighting, Second Edition* by M. David Egan, PE, and Victor Olgyay, AIA, McGraw-Hill, 2002.

"Daylighting Design" by Benjamin Evans, in *Time-Saver Standards for Architectural Design Data*, McGraw-Hill, Inc., 1997.

*Daylighting for Sustainable Design* by Mary Guzowski, McGraw-Hill, Inc., 1999.

*Daylighting Performance and Design* by Gregg D. Ander, John Wiley & Sons, 1997.

*Sustainable Building Technical Manual*, Public Technology Institute, 1996. (www.pti.org)

## Definitions

**Glazing Factor** is the ratio of interior illuminance at a given point on a given plane (usually the work plane) to the exterior illuminance under known overcast sky conditions. LEED uses a simplified approach for its credit compliance calculations. The variables used to determine the daylight factor include the floor area, window area, window geometry, visible transmittance ($T_{vis}$) and window height.)

**Daylighting** is the controlled admission of natural light into a space through glazing with the intent of reducing or eliminating electric lighting. By utilizing solar light, daylighting creates a stimulating and productive environment for building occupants.

**Non-Occupied Spaces** include all rooms used by maintenance personnel that are not open for use by occupants. Included in this category are janitorial, storage and equipment rooms, and closets.

**Non-Regularly Occupied Spaces** include corridors, hallways, lobbies, break rooms, copy rooms, storage rooms, kitchens, restrooms, stairwells, etc.

**Regularly Occupied Spaces** are areas where workers are seated or standing as they work inside a building; in residential applications it refers to living and family rooms.

**Visible Light Transmittance** ($T_{vis}$) is the ratio of total transmitted light to total incident light. In other words, it is the amount of visible spectrum (380–780 nanometers) light passing through a glazing surface divided by the amount of light striking the glazing surface. A higher $T_{vis}$ value indicates that a greater amount of visible spectrum incident light is passing through the glazing.

| SS | WE | EA | MR | EQ | ID |
|---|---|---|---|---|---|
| Credit 8.2 | | | | | |

1 point

EB

# Daylight & Views

## Views for 90% of Spaces

### Intent

Provide for the building occupants a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.

### Requirements

Achieve direct line of sight to the outdoor environment via vision glazing between 2'6" and 7'6" above finish floor for building occupants in 90% of all regularly occupied areas. Determine the area with direct line of sight by totaling the regularly occupied square footage that meets the following criteria:

- ❑ In plan view, the area is within sight lines drawn from perimeter vision glazing.
- ❑ In section view, a direct sight line can be drawn from the area to perimeter vision glazing.

Line of sight may be drawn through interior glazing. For private offices, the entire square footage of the office can be counted if 75% or more of the area has direct line of sight to perimeter vision glazing. For multi-occupant spaces, the actual square footage with direct line of sight to perimeter vision glazing is counted.

### Potential Technologies & Strategies

Design the space to maximize daylighting and view opportunities. Strategies to consider include lower partition heights, interior shading devices, interior glazing, and automatic photocell-based controls.

## Summary of Referenced Standard

There is no standard referenced for this credit.

## Approach and Implementation

There are two calculations required to determine achievement of this credit—Direct Line of Sight to Perimeter Glazing and Horizontal View. The Direct Line of Sight to Perimeter Glazing determination is an area calculation, and confirms that 90% of the occupied area is designed so there is the potential for views from regularly occupied areas. It is based on vision glazing (2'6" – 7'6"), and the location of full height interior partitions. Movable furniture and partitions are not included in the scope of this credit calculation. See **Figure 1**.

One successful design strategy for offices locates open plan areas along the exterior walls, while placing private offices and areas not regularly occupied to the core of the building. The Horizontal Views determination confirms that the available views are maintained. It is recommended that the line of sight used for the determination of Horizontal Views is assumed to be 42" to reflect an average seated eye height. Design teams may, however, wish to utilize alternate view heights for areas with non-typical functions. Maintaining the views for spaces near the core is a primary design objective. See **Figure 2**.

Regularly occupied spaces include office spaces, conference rooms and cafeterias. Areas that need not be considered include support areas for copying, storage, mechanical equipment, laundry and restrooms.

## Calculations

Direct Line of Sight to Perimeter Vision Glazing

1. Create a spreadsheet and identify all regularly occupied rooms/areas. Determine the floor area of each applicable room using construction documents.2. Using a floor plan, construct line of sight geometries at each window to

**Figure 1:** Direct Line of Sight to Perimeter Vision Glazing, used in the area determination

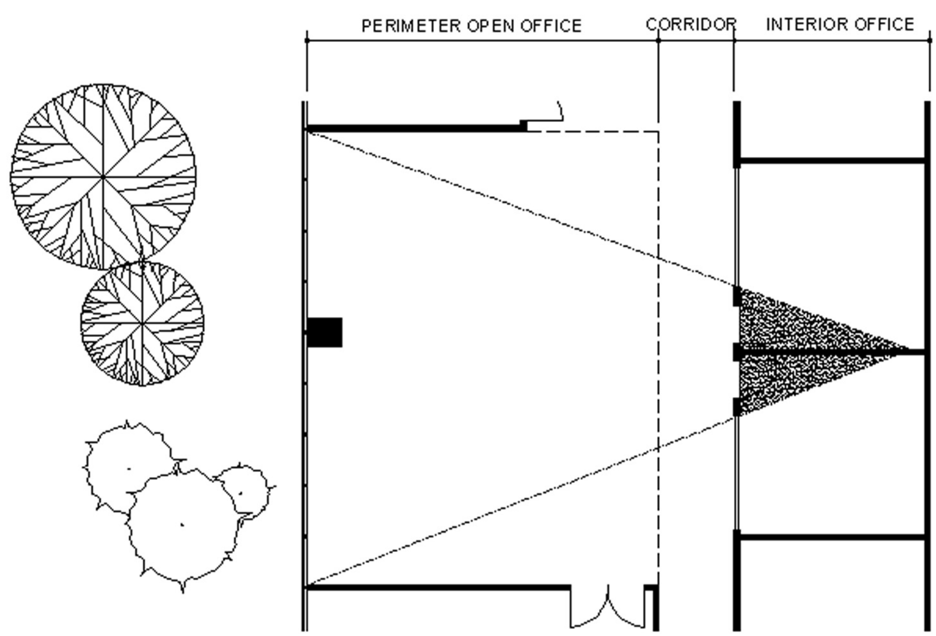
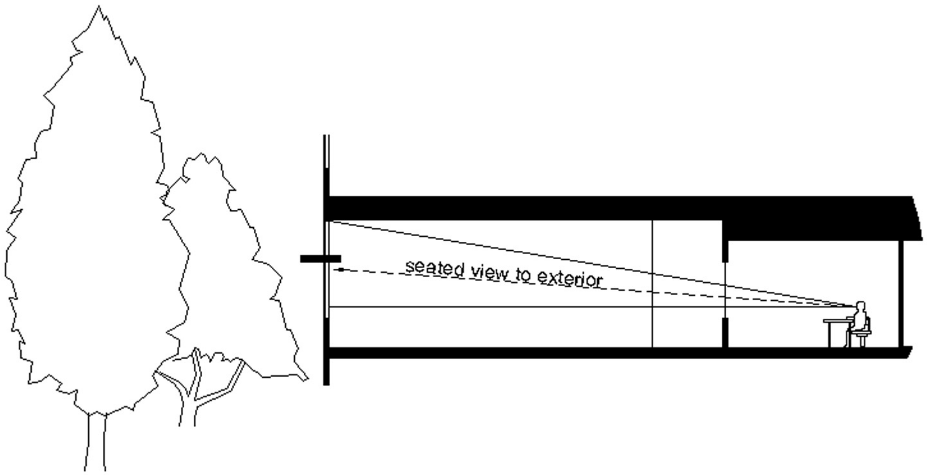


**Figure 2:** Horizontal View at 42", used to confirm access to views






determine the fraction of the regularly occupied room/area that has direct line of sight to the outdoors. Note: line of sight can pass through interior glazing but not through doorways with solid doors.

2. For private offices, if the percentage of floor area with direct line of sight is equal to or greater than 75% (i.e., only the corners are non-compliant), you may enter the entire square footage of that room in the spreadsheet (see **Table 1**) as meeting the credit requirement. If less than 75% of the room has direct line of sight, you must estimate the compliant floor area and enter that value in the spreadsheet.
3. For multi-occupant spaces, such as open work areas and conference rooms, estimate the actual square footage with direct line of sight to perimeter vision glazing.

### Horizontal View at 42 Inches

1. Using representative building sections, draw a line at 42". (average seated eye height) across the section to establish the height of the perimeter glazing and any obstruction to it. Draw one or more representative sight lines from a point at 42" in the regularly occupied space(s) to the perimeter vision glazing. (See **Figure 2**.)
2. For each space where the view, taken at 42". above the floor, is maintained, enter a YES in the spreadsheet in the "Horizontal View" column of **Table 1**. If a room has direct line of site on the

**Table 1:** Determination of Compliance

| Room | Regularly Occupied Floor Area [SF] | Plan Area of Direct Line of Sight to Perimeter Vision Glazing [SF] | Calculated Area of Direct Line of Sight to Perimeter Vision Glazing [SF] | Horizontal View at 42 Inches [Yes/No] | Compliant Area [SF] |
|---|---|---|---|---|---|
| 101 Office | 820 | 790 | 820 | Yes | 820 |
| 102 Conference | 330 | 280 | 330 | Yes | 330 |
| 103 Open Office | 4,935 | 4,641 | 2,641 | Yes | 4,641 |
| 104 Office | 250 | 201 | 250 | No | 0 |
| 105 Office | 250 | 175 | 175 | Yes | 175 |
| Total | 6,585 | | | | 5,966 |
| Percent Access to Views [5,966/6,585] 90.5% Credit Earned | | | | | |

floor plan but does not have an unobstructed view at 42”, the floor area of that room may not be counted as meeting the credit requirement and should be marked as NO in the table.

Total the area that is determined to meet all criteria above and divide it by the total regularly occupied area to determine if the building meets the 90% access to views requirement.

## Exemplary Performance

This credit may be eligible for exemplary performance under the Innovation in Design section however, there is no prescribed threshold for determination of exemplary performance. Projects will be evaluated on a case-by-case basis.

## Submittal Documentation

This credit is submitted as part of the **Design Submittal**.

The following project data and calculation information is required to document credit compliance using the v2.2 Submittal Templates:

- ❑ Complete the template calculation spreadsheet to demonstrate overall access to views from occupied spaces. The following data is required for input in the template: occupied space identification, occupied space area (sq. ft.), and area (sq.ft.) of each occupied space with direct access to views.
- ❑ Provide copies of the applicable project drawings showing the line of sight from interior spaces through exterior windows in both plan and sectional views.
- ❑ Provide a narrative describing any special occupancy areas that have been excluded from compliance. The narrative should include a detailed description of the space function and an explanation as to why the inclusion of views would hinder the normal tasks/function of each excluded area.

## Considerations

### Cost Issues

Additional glazing required to provide access to views can increase initial costs for a project and can lead to increased heat gain if not designed properly. Glazing provides less insulating effects compared to standard walls, resulting in higher energy use and requiring additional maintenance. However, offices with sufficient natural daylight and a visual connection to the outdoor environment have proven to increase occupant productivity and comfort. Daylighting can significantly reduce artificial lighting requirements and energy costs in many commercial and industrial buildings, as well as schools, libraries and hospitals. Daylighting, combined with energy-efficient lighting and electronic ballasts, can reduce the lighting power density in some office buildings by up to 30%.

### Environmental Issues

Providing access to views of the outdoors, through the incorporation of vision glazing, enables building occupants to maintain a visual connection to the surrounding environment. The additional glazed area may reduce the need for electric lighting of building interiors, resulting in decreased energy use. This conserves natural resources and reduces air pollution impacts due to energy production and consumption.

When designing for maximum views and daylighting, designers must evaluate and balance a number of environmental factors, such as heat gain and loss, glare control, visual quality and variations in daylight availability. Appropriate shading devices, to control glare and direct beam illumination, must be utilized to provide the highest level of environmental comfort.

## Resources

Please see the USGBC website at www.usgbc.org/resources for more specific resources on materials sources and other technical information.

### Websites

**Analysis of the Performance of Students in Daylit Schools**

www.innovativedesign.net/studentperformance.htm

Nicklas and Bailey's 1996 study of three daylit schools in North Carolina.

**The Art of Daylighting**

www.edcmag.com/CDA/ArticleInformation/features/BNP__Features__Item/0,4120,18800,00.html

This Environmental Design + Construction article provides a solid introduction to daylighting.

**New Buildings Institute's Productivity and Building Science Program**

www.newbuildings.org/downloads/FinalAttachments/PIER_Final_Report(P500-03-082).pdf

Provides case studies and report on the benefits of daylighting.

**Radiance Software**

http://radsite.lbl.gov

Free daylighting simulation software from the Lawrence Berkeley National Laboratory

**The Whole Building Design Guide Daylighting**

www.wbdg.org/design/daylighting.php?r=ieq

**Lighting Controls**

www.wbdg.org/design/electriclighting.php?r=ieq

The Daylighting and Lighting Controls sections provide a wealth of resources including definitions, fundamentals, materials and tools.

### Print Media

"Daylighting Design" by Benjamin Evans, in *Time-Saver Standards for Architectural Design Data*, McGraw-Hill, Inc., 1997.

*Daylighting for Sustainable Design* by Mary Guzowski, McGraw-Hill, Inc., 1999.

*Daylighting Performance and Design* by Gregg D. Ander, John Wiley & Sons, 1997.

*Sustainable Building Technical Manual*, Public Technology Institute, 1996. (www.pti.org)

## Definitions

**Daylighting** is the controlled admission of natural light into a space through glazing with the intent of reducing or eliminating electric lighting. By utilizing solar light, daylighting creates a stimulating and productive environment for building occupants.

**Direct Line of Sight to Perimeter Vision Glazing** is the approach used to determine the calculated area of regularly occupied areas with direct line of sight to perimeter vision glazing. The area determination includes full height partitions and other fixed construction prior to installation of furniture.

**Horizontal View at 42 Inches** is the approach used to confirm that the direct line of sight to perimeter vision glazing remains available from a seated position. It uses section drawings that include the installed furniture to make the determination.

**Non-Occupied Spaces** include all rooms used by maintenance personnel that are not open for use by occupants. Included in this category are janitorial, storage and equipment rooms, and closets.

**Non-Regularly Occupied Spaces** include corridors, hallways, lobbies, break rooms, copy rooms, storage rooms, kitchens, restrooms, stairwells, etc.

| SS | WE | EA | MR | EQ | ID |
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| Credit 8.2 | | | | | |

**Regularly Occupied Spaces** are areas where workers are seated or standing as they work inside a building; in residential applications, it refers to the living and family rooms.

**Vision Glazing** is that portion of exterior windows above 2'6" and below 7'6" that permits a view to the outside of the project space.

## Case Study

**National Association of Realtors, Headquarters Building**

**Washington, D.C.**

Owner: The National Association of Realtors

The National Association of Realtors Headquarters Building in Washington D.C. achieved LEED® v2.0 Gold in 2005. The project's successful completion of EQ Credit 8 is notable considering it is located in a city that has a floor-to-ceiling height restriction. Due to full-height glazing on the exterior walls and a floor plan with a narrow footprint, 75% of the regularly occupied spaces are exposed to daylight, and 100% of the critical visual task areas have views of the outdoors.