FEMP

Federal Energy Management Program

FEMP Energy Efficiency and Indoor Environmental Quality Assessment Guide

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Disclaimer

Authors

The authors of this report are:

Lauren Esaki-Kua, Pacific Northwest National Laboratory (PNNL)

Kevin Keene, PNNL

Kieren McCord, PNNL

Max Martell, PNNL

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Contributors:

Allison Ackerman, Federal Energy Management Program

Jessica Baweja, PNNL

Rengie Chan, Lawrence Berkeley National Laboratory

Ammar Dehwah, PNNL

List of Acronyms

dB	Decibels
DOE	U.S. Department of Energy
FEMP	Federal Energy Management Program
H-BEST	Healthy Buildings and Energy Support Tool
HVAC	Heating, Ventilation, and Air Conditioning
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
IES	Illuminating Engineering Society
LED	Light Emitting Diode
MERV	Mechanical Efficiency Rating Value
$PM_{2.5}$	Particulate Matter (<2.5 microns)
TVOC	Total Volatile Organic Compound
VOC	Volatile Organic Compound

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1.0 Introduction

The purpose of this document is to provide thorough guidance when preparing for an energy and indoor environmental quality (IEQ) assessment. It provides step-by-step instructions, detailed insights, and practical examples for the various phases of an energy and IEQ assessment.

1.1 Purpose of an energy and IEQ assessment

IEQ encompasses indoor building conditions, such as air quality, thermal comfort, acoustics, and lighting. IEQ has become a growing field of interest among a diverse range of stakeholders (e.g., building owners and managers) due to the effects it has on occupant health and productivity. Moreover, IEQ improvement strategies often provide overlapping opportunities for increasing building energy efficiency, creating a win-win situation for building operations.

The purpose of conducting an energy and IEQ assessment typically falls within one of the following categories:

- **Benchmarking** – Comparing a building's performance against established standards, best practices, or similar buildings. This involves collecting data throughout the building, unbiased by locations and metrics.
- **Investigating a known concern** – Investigating specific complaints from occupants with data collected in certain rooms or targeting specific metrics of concern.
- **Ensuring building improvements address occupant concerns** – Comparing IEQ before and after a renovation or building improvement. This involves prioritizing areas that have undergone or will undergo renovation, and/or focusing on metrics that the renovations are intended to address.

It is important to clearly establish the purpose of the building's assessment because it will determine which metrics to collect, which monitors to purchase based on the metrics they can measure, and where to place monitors within the building.

The outcome of the assessment should include an analysis of energy use, a summary of the IEQ measurements, and identified actionable recommendations to improve IEQ and energy efficiency. The assessments described in this guide are intended to investigate a building's energy consumption and IEQ performance and ways to improve both. This is not a guide for using a specific healthy building rating system or performing an exhaustive research study.

1.2 Data

There are three types of data or information that can be collected for an energy and IEQ assessment:

- Measurements from the various IEQ monitors
- Subjective feedback from occupants collected through a survey or focus group
- Information about the building itself, such as occupancy, geometry, building construction, energy systems, and equipment, collected through building walkthroughs.

1.2.1 Measuring IEQ data

Monitors collect data on air quality and thermal metrics, such as temperature, humidity, particulate matter, and carbon dioxide, over a given period. The measured data are compared to high-performance benchmarks—or the levels needed to actively promote optimal occupant health, comfort, and productivity. Table 1 shows a summary of common IEQ metrics and possible benchmarks that can be used for schools, hospitals, and offices.

While many metrics can be collected and measured for an IEQ assessment based on your building goals and priorities, the main categories to consider are air quality, acoustics, lighting, and thermal comfort. The following is a description of some common metrics in these categories.

- **Carbon dioxide** – Studies have shown that an indoor environment with high levels of CO_2 concentration may be associated with lower work performance, reduced absenteeism, sick building syndrome symptoms, and odor complaints, as well as improved task performance (Du et al. 2020; Mendell et al. 2013). Some studies have found that CO_2 itself may not be harmful to occupants at the levels typically found in buildings; rather, it is a proxy for ventilation rate and other indoor air quality (IAQ) pollutants, such as human bioeffluents (Zhang et al., 2017; Azuma et al., 2018). CO_2 levels are often correlated to ventilation rate, which is the principle driver for reducing indoor air pollutants.
- **Particulate matter** – Particulate matter is a predominant indoor air pollutant. Small particulates less than 2.5 microns in diameter ($PM_{2.5}$) can enter the lungs and bloodstream when inhaled and pose health risks, and is even measured for outdoor air as a part of the Clean Air Act (Morawska et al., 2017; EPA, n.d. a). Common sources of particulate matter include vehicles and industrial processes. These particulates can enter a building through leaks in the envelope, open windows, or through an air handler with insufficient filtration. In the school setting, resuspension from students bringing particles in when entering classrooms and indoor spaces is a significant source of particulate matter (Morawska et al., 2017).
- **Total volatile organic compounds –** Total volatile organic compounds (TVOCs) comprise many different individual volatile organic compounds (VOCs) which can emit into the air from many consumer products, such as paints, furniture, fabrics, perfumes, and cleaning products (Johnson, 2018). Indoor furniture and construction materials can emit VOCs for up to one to two years after construction, depending on the quality of the air supply and circulation in the space (Zhong et al., 2017). VOCs can be sourced from vehicles and introduced through outdoor air. The health impacts of VOCs depend on concentration levels and duration of exposure, and can include irritation to the eyes, nose, and throat, headaches, nausea, and damage to organs (Johnson, 2018). A review of TVOC posited that it is not possible to appropriately assess health hazards from TVOC exposure alone due to the various substances and varying effects they have, and that different methods of TVOC measurement and assessment cannot be easily converted between one another (Salthammer, 2022). The majority of TVOC sensors in IEQ monitors do not produce reliable readings; however, IEQ monitors can still provide value in detecting dynamic TVOC concentration changes (Clements et al. 2019; Demanega et al., 2021). Absolute values, however, are not meaningful for comparing with benchmark values (Demanega et al., 2021) so this metric should be treated with caution if used.

- **Temperature** – The human body continuously dissipates and regulates heat to ambient environments, and air temperature is the major factor in such interactions. Several studies have demonstrated that air temperature significantly influences occupant productivity and satisfaction (Nishihara & Tanabe, 2007; Tham, 2004). Although there are multiple factors that affect thermal comfort, temperature is one of the most influential and most interpretable. Temperature can vary significantly between seasons, so it is important to consider the year-round effects of a solution when determining the best improvement.
- **Humidity** – Humidity plays a role in air quality and thermal comfort. High humidity levels can create environments conducive to mold growth (CDC, 2015), and low humidity levels may create a hospitable environment for virus transmission. Research suggests that when indoor relative humidity is below 40%, there are fewer water particle obstacles in the air, making it easier for small infectious aerosols to travel farther (Ahlawat et al., 2020). Dry air may also impair respiratory immunity (Moriyama et al., 2020; Taylor, 2020). Humidity can vary significantly between seasons, so it is important to consider the year-round effects of a solution when determining the best improvement.
- **Noise** – Sound is measured in decibels (dB), which is a logarithmic unit. Thus, a sound 10 times greater in intensity than 0 dB will be measured as 10 dB, while a sound 100 times more intense than 0 dB will be measured as 20 dB. A normal conversation is about 60 dB, and a motorcycle engine running is about 95 dB (CDC, 2019). Repeated exposure to high noise levels can damage hearing, and guidelines limiting occupational noise exposure begin at 85 dBA for an 8-hour day, where the A in "dBA" signifies a frequency weighting that closely matches human hearing.
- **Illuminance** – Horizontal illuminance is the density of light (lumens) per surface area and is measured on the horizontal plane (e.g., a desk), and vertical illuminance is measured on the vertical plane, typically to simulate the light entering the eye of an occupant looking forward. Sufficient illuminance is important when performing visual tasks for occupants to accurately view objects and their surroundings. A literature review of eleven studies of visual performance found a significant rise in speed and accuracy of various work tasks from low to medium light levels and smaller improvements to performance at higher illumination levels (Rea, 2018). Illuminance can be difficult to collect with monitors in occupied buildings because it is difficult to find locations that do not interfere with occupants' regular activity and because illuminance varies significantly by measurement location. This subject is discussed in more detail in Section **Error! Reference source not found.**.

Table 1. Example of Benchmarks for IEQ Metrics

IEQ Metric	Benchmark	Offices	Hospitals	Schools
Carbon Dioxide[T]	Acceptable	<965 ppm[*3]	<580 ppm[*12]	<1,010 ppm (lower grades) <1,210 ppm (upper grades)[*3]
	High-Performance	<730 ppm[*1]	<460 ppm[*2]	<830 ppm (lower grades) <970 ppm (upper grades)[*2]
Particulate Matter ($PM_{2.5}$)	Acceptable	<25 $\frac{ug}{m^3}$[*13]	<25 $\frac{ug}{m^3}$[*13]	<25 $\frac{ug}{m^3}$[*13]
	High-Performance	<15 $\frac{ug}{m^3}$[*13]	<15 $\frac{ug}{m^3}$[*13]	<15 $\frac{ug}{m^3}$[*13]
Temperature	Acceptable	68 – 76 °F[*4] (20 – 24.4 °C)	68.5 – 79 °F[*3,5] (20 – 26 °C)	68 – 79 °F[*6] (20.5 – 26 °C)
	High-Performance	68 – 76 °F[*4] (20 – 24.4 °C)	70 – 74 °F[*5] (21 – 24 °C)	69 – 74 °F[*6] (20.5 – 23.5 °C)
Humidity	Acceptable	30 – 60%[*7]	30 – 60%[*7]	30 – 60%[*7]
	High-Performance	40 – 60%[*8]	40 – 60%[*8]	40 – 60%[*8]
Noise	Acceptable	<55 dBA[*10]		<55 dBA[*10]
	High-Performance		<30 dBA[*9]	<35 dBA[*10]
Horizontal Illuminance	Acceptable	>300 lux[*11]	>200 lux[*11]	>200 lux[*11]
	High-Performance	>500 lux[*11]	>400 lux[*11]	>500 lux[*11]

Acceptable benchmarks *refer to the level of a metric that is considered to significantly reduce the risk of adverse health effects, whereas* ***high-performance benchmarks*** *refer to the level of a metric actively promoting optimal health, comfort, and productivity of occupants. The achievement of high-performing conditions is encouraged, and acceptable conditions are shown as a reference point.*

[T] Carbon dioxide values are based on ventilation values from each of the sources, converted to carbon dioxide values based on typical human carbon dioxide generation rates. These values should be compared to steady-state readings, i.e., values at maximum typical occupancy.

(1) WELL v2 A06 Enhanced Ventilation Design: https://v2.wellcertified.com/en/wellv2/air/feature/6
(2) WHO (2021a)
(3) ASHRAE 62.1-2022 Ventilation and Acceptable Indoor Air Quality: https://www.ashrae.org/technical-resources/bookstore/standards-62-1-62-2
(4) OSHA policy on IAQ: https://www.osha.gov/laws-regs/standardinterpretations/2003-02-24
(5) Derks et al. (2018); Skoog et al. (2005); Azizpour et al. (2013); Kim and Song (2020); Mora and Athienitis (2001); Smith and Rae (1976)
(6) New Jersey Work Environment Council (2014); Penn State (2015); NMPSFA (2013)
(7) EPA (n.d., b)
(8) Ahlawat (2020)
(9) Berglund et al. (Ed.) (1999)
(10) ANSI S12.2 Acceptable Room Sound Levels: https://www.archtoolbox.com/room-sound-levels/
(11) IES (2011) D. Dilaura, K. Houser, R. Mistrick, G. Steffy, The Lighting Handbook: Reference and Application, 10th Edition, Illuminating Engineering Society of North America (IES), New York, NY, 2011.
(12) ASHRAE 170-2021 Ventilation of Healthcare Facilities: https://www.techstreet.com/ashrae/standards/ashrae-170-2021?product_id=2212971
(13) WHO (2021b)

1.2.2 Collecting occupant feedback

In addition to logged data, energy and IEQ assessments ideally collect qualitative feedback from building occupants on their satisfaction with the building through a focus group or survey. Collecting information about the building and its occupants before conducting a survey or focus group can help identify which issues or locations in the building to ask clarifying questions about. With the qualitative information gathered from either a focus group or survey, the quantitative data collected from the monitors can be better contextualized to address the building's operation, maintenance, and energy efficiency for improved IEQ.

1.2.3 Gathering building information

Finally, information about the building and its occupants can be collected from a walkthrough form or checklist. The information can be used to assess the building's energy use and help identify building improvements with co-benefits for improving IEQ and energy efficiency. Some resources to assist in evaluating the building's energy use include Building Energy Asset Score and ENERGY STAR Portfolio Manager, which are open-sourced rating and management platforms that rate buildings' energy performance and provide improvement recommendations.

2.0 Pre-assessment Steps

2.1 Roles and responsibilities

Prior to conducting your study, determine who on your team will be responsible for key roles during the assessment. Delegating roles ahead of time will help streamline the data collection and analysis process, reducing the likelihood for miscommunication and delays.

The primary roles and responsibilities include:

- **Project lead (on site or remote)** – Responsible for coordinating the assessment. Includes setting up the monitors, creating a short survey or more in-depth focus group questions to collect qualitative information from staff about the building, and providing the building walkthrough questions to the main site contact. This person could be at the agency/organizational level, site level, or a hired contractor/consultant.
- **Main site contact (on site)** – Provides access to the building and important background information about the site. This person could be a building manager, operator, engineer, or interior designer and should be familiar with the building envelope, lighting, and heating, ventilation, and air conditioning (HVAC) system.
- **Survey/focus group coordinator (on site)** – Coordinates the socialization and distribution of a short survey or more in-depth focus group with staff to collect qualitative information. This coordinator should have access to a listserv for the building or other channels of communication. This role is not responsible for the creation or analysis of the survey.
- **Data monitor coordinator (on site)** – Responsible for troubleshooting monitors as needed. An engineer, IT specialist, or administrator may be appropriate for this role.
- **Data analyst (on site or remote) –** Cleans, analyzes, and presents data during and after the data collection. Data are inclusive of survey, IEQ, and building energy data. Should be familiar with Excel or another data program (R, Python, Tableau, etc.).

2.2 Monitor selection and procurement

2.2.1 Number of monitors

The next step is to select the appropriate quantity of monitors for your site assessment. Consider how many monitors you will need to assess the building. For most buildings, it is recommended to have at least 10 monitors to capture the spatial differences that can exist in parts of a building. If your site needs to assess more than 10 spaces, you will need to purchase more than 10 monitors, or alternatively move the monitors part way through the monitoring period to capture data from more rooms. Refer to Section 3.1.3 for how to estimate the number of monitors based on the size of your building.

2.2.2 Metric considerations for monitor selection

Once you have determined the number of monitors your site will need, consider the differences in monitors available on the market that will fit your needs. There are a range of IAQ monitors that vary by metrics, cost, data storage and transfer capabilities, customer support, and hardware and software requirements. Consider which metrics are most important for your site, budget, and data preferences to select the monitor that will best serve your purposes.

Appendix E provides a non-exhaustive list of some IEQ monitors currently available on the market. There are more manufacturers and models than reviewed in this analysis. You are encouraged to research additional monitors to find the right model to fit your needs and budget.

The following categories should be considered for monitor acquisition, and a sample template for conducting a monitor comparison that fits your needs is included in Appendix E:

- **Pricing** – The price of each sensor is an important consideration. Some sensors require a subscription fee while others offer additional analysis services for an added fee. Note: Some federal purchasers may be allowed to purchase monitors but not pay subscription fees; therefore, federal users should consider acquisition rules in the selection process.
- **Intended user** – Some devices are intended for researchers and some for consumers. Consumer-oriented monitors are typically easier for the average on-site person to set up and use with minimal support.
- **Metrics –** It is recommended to find a single monitor that can measure temperature, humidity, carbon dioxide, and particulate matter, which are the primary metrics used in Federal Energy Management Program (FEMP) studies. Some monitors collect additional parameters that may provide useful information to address specific concerns.
- **Data access, storage, and transfer** – It is ideal to have monitors that can transfer data both through Wi-Fi and manually if public Wi-Fi is not available at a site. If there is reliable Wi-Fi at the site, the ability to transfer data through Wi-Fi only will be sufficient. Consider if the product offers a dashboard or mobile app that may make it easier to view and download the data remotely. For outdoor monitors, it can be difficult to find viable outdoor placement locations that are within Wi-Fi range. Having a local data storage and transfer option in the selected outdoor monitor may be necessary.
- **User experience and customer support** – User experience with monitors and companies can make a huge difference in IEQ assessment success; however, it is difficult to fully gauge this parameter until a monitor has been purchased and used.
- **Security and information technology restrictions** – Consider the information technology (IT) restrictions of the site and whether an external sensor may be connected to the local Wi-Fi. Some sites have a guest Wi-Fi network, but it may timeout after a short period. Consider if there are any apps or software required to set up the devices or download the data. Most federal IT systems have rules around whether devices can be connected to government-owned IT equipment.
- **Maintenance** – Monitors often require some maintenance or calibration in their lifetime. The recommended lifetime of the device, typically in the range of 3 to 5 years if used continuously, is an important consideration for repurchasing.
- **Accuracy –** Sensors will have a degree of accuracy and sensing range that is usually specified. The accuracy of readings is an important consideration when interpreting the data collected. A separate research study has found that sensor accuracy can vary significantly

from product specifications in practice, users should refer to resources such as AQ-SPEC (https://www.aqmd.gov/aq-spec) and Empower Procurement Product Testing Hub ((https://energyproductevaluations.org/product_categories/carbon-dioxide-sensors/) for reference.

- **Logging frequency** – A monitor that can log at 10-minute intervals or less is recommended to capture the time-varying nature of IEQ parameters in occupied buildings.

2.3 Monitor testing and calibration

Dedicate time to understanding how to operate your monitors and what format the data will come in. For example, some monitors require an additional mobile application be downloaded for the setup and operation of the monitor. Most monitors on the market provide the option to download data in a.csv format, but the time intervals and other variables will differ in how the data are presented. This will also be a good time for the data monitor coordinator to get involved and learn the functionalities of the monitor.

All monitors will eventually require calibration or replacement, so review the manufacturer's recommendations ahead of time, and test the monitors to check that they give similar readings to each other and do not have any other technical issues. If there are any issues or questions with the monitors, reach out to the manufacturer's customer service to resolve them ahead of time and avoid confusion and delays during the assessment.

2.4 Supplemental equipment

Beyond the IAQ monitors, we have found from past IEQ assessments that additional equipment helps to set up the monitors onsite with greater ease. Some of the items that are useful for the monitor set up process include:

- **Smart tablet** – If there are IT restrictions on downloading apps for setting up the monitors or connecting the monitors to Wi-Fi to transfer data, a smart tablet can be used and connected to a guest Wi-Fi network in many cases.
- **Cable ties and gaff tape** – These are useful to prevent tripping hazards from wiring connected to the monitors.
- **Clipboard** – If using paper copies of a walkthrough inspection form, a clipboard will help with notetaking on the form.
- **Power strips or extension cords** – If there are limited outlets onsite, these will ensure a place to plug in the monitors.
- **Tote bag** – May be useful to carry equipment around.
- **Laser measuring device or measuring tape** – Use these tools to measure the room and window dimensions if they are not available on floor plans.
- **Keyboard duster** – Useful to clean monitor vents if they get clogged.
- **Adhesive strips** – Attach sensors to walls with adhesive strips if there is limited table space.

2.5 Remote assessment management

The next step after testing your monitors and gathering your supplemental equipment is to put together a set of training and instructional materials for installing the monitors, gathering the data, and determining what to expect.

A kickoff meeting will be necessary to get everyone involved in the assessment on the same page. The site-specific training and instructional materials can be shared during this meeting to provide the steps of how to set up the monitors, where they will be placed, and how to use them in conjunction with the additional equipment.

A template for a set of training and instructional materials might include:

- Expectations for the assessment and the approximate timeframe.
- A diagram of the pieces of equipment needed for the monitor and information on additional equipment that will be used for data collection.
- A step-by-step process of how to turn on, connect, and run the monitor.
- Tips and best practices for where to place monitors in a room and outdoors, if monitoring outdoor conditions (i.e., in locations that represent what IEQ occupants experiences regularly, placing monitors at chest or head level of a seated or standing occupant). See Sections 3.1.5 and 3.1.6 for guidance.
- Guidance on photo documentation of where monitors are installed in each location (see Section 3.1.7).

The figures in Appendix A are example excerpts from a set of training slides from a kickoff meeting at a federal facility. Other slides include the step-by-step process of installing the monitors, such as how to turn on the monitors, how to connect them to the specific mobile application, how to connect the monitor to Wi-Fi, and how to track the specific device.

If the site assessment is being conducted remotely, it is helpful to provide an equipment checklist to the main site contact. Using a checklist will ensure all provided equipment is accounted for at the end of the study when it is ready to be returned. Taking photos of the equipment will also be useful to provide to the site as reference to what was included in the assessment.

2.6 Focus group or survey design

While data from the monitors will provide a quantitative assessment on the building's IEQ conditions, surveying or interviewing building occupants can provide contextual information to form a more comprehensive understanding about the IEQ conditions. Conducting focus groups or surveys provides the opportunity to supplement data with occupant perceptions on the felt experience of the building, as well as additional information about occupant behaviors and schedules or events that would produce anomalous data recordings.

Determine whether the site you are assessing has the time and ability to accommodate a focus group or if a survey will be more amenable to occupants' limited schedules. Focus group discussions generally require 45-60 minutes of participants' time to engage answering questions around indoor comfort levels and any issues they notice. Surveys can be administered online and limited to 10 questions to ensure they take no longer than 5–10 minutes.

When creating questions for focus groups or surveys, consider asking about occupant experiences during different times of year to capture information about the impacts of seasonality on indoor conditions, especially if you are only collecting data in one season. There are existing IEQ survey services that can be purchased, for example, the Center for Built Environment Occupant Survey (https://cbe.berkeley.edu/resources/occupant-survey/). This platform makes it easy to distribute the survey, see the results, and compare to a database of other buildings easily. Occupant surveys can also be created in-house; an example survey and focus group questions are provided in Appendix B.

2.7 Walkthrough building information

Gathering background information about the facility, such as floor plans, mechanical plans, other audit information, and facility reports will be helpful in evaluating the baseline of the building and in thinking about desired outcomes when making IEQ improvements.

Useful information to collect before the start of the study may include:

- Building envelope information, such as window access, U-value, and presence of drafts
- HVAC information, such as system type, age, and condition
- Lighting information, such as bulb wattage and fixture type
- Building occupancy and building closures during study
- Presence of air purifiers or other filtration.

Appendix C shows a form template that can be completed with this information. If there are existing site sustainability reports or energy audit reports, they can be leveraged to gather this information and then updated with any changes since the report was completed. The General Services Administration's Total Workplace Scorecard[1] is a resource that collects this type of information for office buildings and provides a score based on the responses, which can be helpful for tracking progress over time toward healthy buildings design strategies.

2.8 Lighting simulation

The density of light falling on a surface area, known as illuminance, is a common measure of the amount of light in a room. It is typically measured at a horizontal work plane height of 2.5 feet, or about the height of a desk. Sufficient horizontal illuminance is crucial for visual tasks, enabling accurate perception of objects and surroundings. There are three possible approaches for assessing horizontal illuminance: monitors, the lumen method, and simulations.

- **Monitors** – Although there are monitors that can measure and log illuminance data, they require a level of background knowledge on lighting science and light sensors to comprehensively depict the lighting performance of a room and building with measured data. Light measurements can be very sensitive to variables such as the sensor's angle, location in room, height from ground, shadows, and time of day and year for windowed locations. There

[1] https://sftool.gov/tws

are monitors that can log illuminance data over time, but they are not feasible in regularly occupied facilities as the ideal locations for placing these monitors will interfere with occupants' regular activities. Compared to other IEQ metrics, many lighting measurements need to be taken throughout each space to properly characterize the illuminance in a room. Additionally, high-quality lighting sensors can be expensive compared to other IEQ sensors.

- **Lumen method** – The lumen method is a technique used by lighting designers to estimate the average horizontal illuminance in a room by calculating the total lumens reaching the work plane and dividing it by the plane area. However, the illuminance calculated under this method will give an average value that is only representative if there is uniform overhead fixture spacing, rectangular room shapes, non-sloped ceilings, and no variation in overhead fixture type. This may not be the case for all spaces. This method will not account for contributions from daylighting or task lighting either. The equation for estimating the average horizontal illuminance using the lumen method is given below:

$$E_H = \frac{(No. luminaires) * (\frac{lamps}{luminaire}) * (\frac{lumens}{lamp}) * CU * LLF}{work\ plane\ area}$$

  where E_H is the average horizontal illuminance, CU is the coefficient of utilization, and LLF is the lighting loss factor, which is the product of several specific factors such as lamp depreciation, dirt depreciation, and ballast factor. Typically, the LLF ranges from 0.65 to 0.85 depending on the light source, with generally lower values for fluorescent lamps due to lower ballast factors and greater depreciation over time. The CU accounts for the light loss due to the fixture design and ceiling reflectance properties and can be estimated by looking up values from tables such as in the IES Handbook and from manufacturer information. The range for the CU can vary significantly, but usually falls between 0.6 and 0.8. More information is available in ANSI/IES LS-6-20: *Lighting Science: Calculation of Light and its Effects*. Many of the inputs required to complete this method can be difficult to obtain from a site visit unless there are detailed records of lamp and ballast manufacturer information available, so assumptions may be required to use this method.

- **Simulations** – There are several software programs that can be used for lighting simulations, including AGi32, Radiance, and ClimateStudio, each with their own benefits. Honeybee Tools, an open-source software toolkit primarily used for daylighting and energy analysis, is highly customizable, provides quick and accurate lighting calculations, and integrates easily with Rhino 3D CAD software, or other geometry modeling software. Honeybee uses Radiance as the lighting engine, which is itself a highly validated and open-source simulation program, but Honeybee provides a much simpler and easier to learn user interface than using Radiance directly. It is important to note that a simulation provides only an approximation, and actual illuminance values may vary based on the assumptions used in the model.

Regardless of the software chosen, the simulation will require the following information:

- Dimensions of the room or space (length, width, floor-to-ceiling height, work surface height). Floor plans can be used for dimensions and layout of a room, if available, or the dimensions will need to be measured with a measuring device.

- Geometry information for each luminaire in the room (number of lamps, position, orientation, angle, mounting type, and height). Even small variations can change the lighting results significantly.
- Information on the bulbs (lamp type, e.g., fluorescent, light emitting diode (LED), halogen; lamp and ballast manufacturer information; and lamp rated lumen output).
- Unless otherwise known, the reflectance values of the ceiling, walls, and floor are typically estimated to be 80%, 50%, and 20%, respectively.
- A LLF of 0.70 is recommended by the Illuminating Engineering Society (IES) for most situations, which will account for normal depreciation in the amount of light both generated from the light source as it ages and reflected in the room.

To simulate a light source, an IES file is used to represent the photometric properties of the light in the software. The IES developed the file format as a standardized way to virtually characterize different light sources. These files define the distribution of how the light is emitted in all directions from the source for a specific luminaire, based on photometric laboratory measurements. If the manufacturer and model data are known for the light sources in the room, then it is often possible to get the associated IES file from the manufacturer or from an IES file database. It is important to use the exact IES file for the specific light source, as different sources can have significant variations in properties, even with the same type of light. However, if the exact model cannot be identified, try to get an IES file as close as possible to the known information (i.e., number of bulbs, wattage, lumens, color temperature).

For the lumen method approach and the simulation approach, consider what the required inputs will be ahead of time and integrate them with the walkthrough building information form.

2.9 Asset Score

The Building Energy Asset Score is a standardized energy efficiency tool created by the Department of Energy (DOE) that rates the energy efficiency of buildings based on physical and structural inputs of commercial and multifamily residential buildings. Some of the information needed to score a building include:

- Building use type
- Construction properties (roof type, floor type, wall type, window framing type, window glass type)
- Lighting (type, mounting type, wattage, number of lamps, number of fixtures or percentage of area served)
- Heating/cooling (equipment type, cooling and heating sources).

The Building Energy Asset Score provides short and long versions of a data collection form that can be downloaded from the DOE website.[2]

[2] https://buildingenergyscore.energy.gov/resources

2.10 ENERGY STAR Portfolio Manager

ENERGY STAR Portfolio Manager is an interactive online tool that benchmarks the energy use buildings of various use types. Almost 25% of U.S. commercial building space currently uses Portfolio Manager. The tool produces an ENERGY STAR score that compares a building's energy performance to similar buildings nationwide, normalized for weather and operating characteristics. A score of 50 represents median performance, a higher score is better than average, and a lower score is worse than average.

Some of the information needed to evaluate a building's energy use in ENERGY STAR Portfolio Manager includes: building age, size, occupancy, hours of operation, number of staff/employees, percentage of site heated and/or cooled, cooking facilities, and number of walk-in refrigerator/freezer units. The questions that are required for an ENERGY STAR Portfolio Manager analysis are included in Appendix D. This could be integrated into the walkthrough building information form for the assessment.

3.0 IEQ Monitor Data Collection Period

Now that the monitors are obtained and ready, it is time to start the data collection phase. The monitors should be placed in a variety of room types that are regularly occupied. Most importantly, they should be placed in a manner that does not obstruct normal activities and allows people to remain comfortable and productive.

3.1 Monitor deployment

The following steps will help to streamline setting up and deploying the monitors for data collection. Make sure that the building is regularly occupied during the assessment to measure the impact on people.

3.1.1 Monitoring period season

The season of the study has a large impact on data. It is ideal to measure in summer and winter, but if there is only time to collect during one season, be sure to include this as context to the results.

3.1.2 Monitoring period length

It is important to determine the expectations around how long the data collection process will last. Ideally, data would be collected continuously to fully capture the performance of the building; however, that is not reasonable in practice. Given limited resources of on-site personnel to continually collect and organize the data, it is important to balance the amount of data collection with the resources available and prioritize according to building needs. Based on past FEMP assessments, collecting data for more than 5 to 7 weeks tends to have diminishing impacts to the results. However, it is important to regularly review the data being collected—if each week is highly variable, you may need more time. It is ideal to repeat the assessment in heating season and cooling season as IEQ performance can change throughout the year in a building.

3.1.3 Number of rooms to monitor

Ideally, data would be collected from every regularly occupied room in a building to fully characterize the performance; however, given limited resources and time to conduct the assignment, this may not be feasible. In order to collect a significant amount of data to generally characterize the IEQ performance of a building, the recommended method for determining the minimum number of required monitors is provided in Table 2, based on FEMP's experience working in federal buildings. The recommended number of rooms in the table below work well as a general guideline to capture the data needed, but the values are based on assessments in a limited number of buildings.

Table 2. Number of Rooms to Monitor by Building Size

Building size	Minimum % of occupied rooms to monitor
Small to medium sized buildings (100,00 sf and less)	50%
Large buildings (100,000 sf and greater)	33%

3.1.4 Room selection

Select the rooms in the building that are regularly occupied and representative of the IEQ qualities that occupants regularly experience. It will be useful to identify the rooms on a floor plan ahead of placement. The following factors are important to consider for room selection:

- A variety of room types (e.g., open office, conference, classroom)
- Core vs. perimeter spaces
- Orientation (north, east, south, west)
- Zones (e.g., floors, wings)
- Any other building system groupings, such as HVAC zone, light fixture types, or construction materials.

If using an outdoor monitor, it is best to place it out of direct sunlight; for example, on the north side of the building, which will receive less direct sunlight than the south side.

Figure 1 shows an example floor plan and how the monitors could be distributed throughout the rooms. In this example, since the school is less than 100,000 sf, there are approximately 33% of the number of rooms monitored. There is an even distribution of monitors between the perimeter and core and the NESW orientations. There is also a variety of room types selected.

Figure 1. Example floor plan with marked monitor placements

3.1.5 Monitor placement within rooms

Place monitors on a surface approximately three to six feet high to be at chest or head height of someone seated or standing. Be sure that none of the air intakes of the monitor are blocked on any side. Consider the effects of varying temperatures and air quality within a room on the monitor. The monitor placement should be able to capture IEQ metrics representative of what occupants regularly experience in the room. For example, heaters, vents, and windows may be hotter or colder than the part of a room where occupants primarily exist. Similarly, placing monitors near air filters or diffusers that may have higher volumes of airflow may not give representative readings. As a best practice, the monitors should also be placed in areas of the room that will not get in the way of daily activities of occupants (see **Figure *2***).

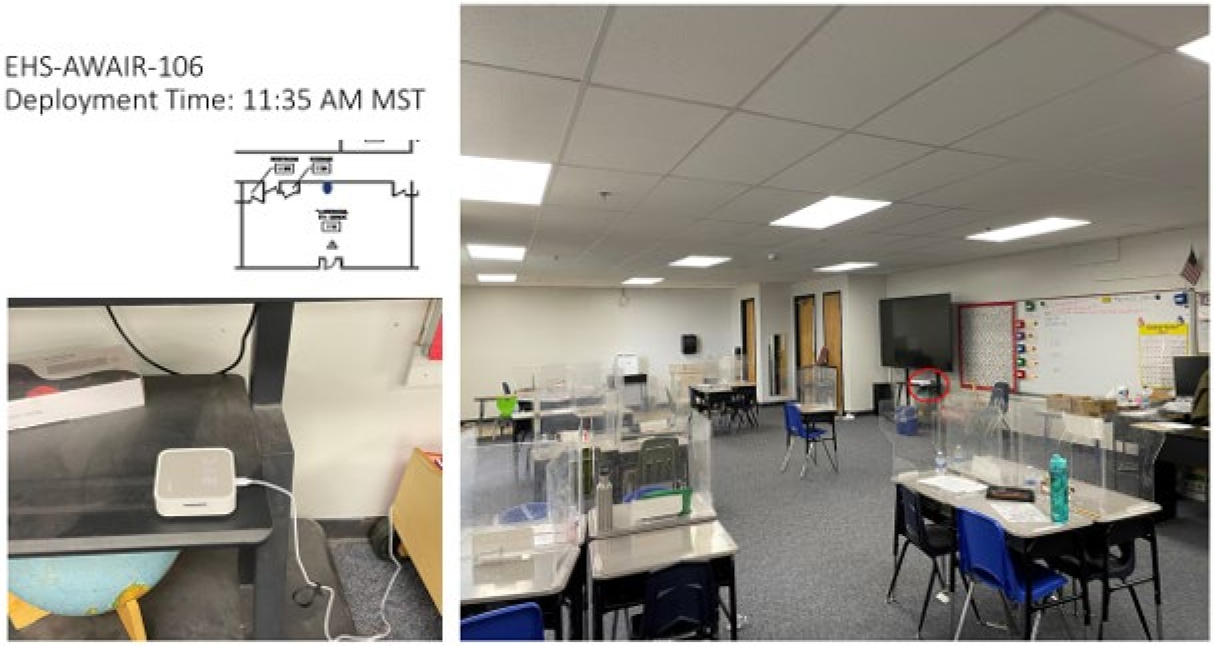

Figure 2. Example monitor placement within a room

3.1.6 Outdoor monitor placement

Because the outdoor environment can have a large influence on indoor conditions, consider including some outdoor measurements while monitoring for IEQ. For outdoor monitors, choose a location to mount the monitor that is convenient to reach and within range of a power outlet if it is not battery powered. Most outdoor monitors can be exposed to the elements if needed, but it is preferable to mount them in locations away from direct sunlight to avoid radiant heat effects. Place the outdoor monitor away from any exhaust vents, localized sources of pollution, and foliage that might house insects, as all of these could interfere with the sensors. Another consideration is the outdoor location's proximity to the site's Wi-Fi connection if the sensor uses Wi-Fi.

3.1.7 Photo documentation

Take many photos that capture room context around the monitor for reference when looking at results, especially if there are team members who are not onsite or not familiar with the site. The photos should be taken from different angles within the room, including windows and overhead lights. Providing wider angle photos can also provide more context for remote team members' understanding the layout of the room. It may be helpful to take photos of building equipment on the walkthrough. Elements to capture in photos may include:

- Cubicle or workstation layout showing partitions and density for open work areas
- Overhead lights and their layout
- Task lighting
- Model and manufacturer information on an overhead lamp and ballast
- Exterior doors, windows, and skylights that show size and quantity
- Exterior facades
- Outdoor air intakes and damper positions
- Air handler units and other equipment such as economizers and energy recovery ventilation systems, if present
- Air filters including mechanical efficiency rating value (MERV) or other rating value
- Heating and cooling equipment
- Supply and return air registers
- Thermostats
- Portable air cleaners
- Cleaning products
- Potential sources of indoor air pollutants such as air fresheners, humidifiers, and printers.

3.1.8 Signs/placards for monitors

Many occupants may be curious about the monitors, so placing “Do not move” or “Do not touch” labels with a short description of their purpose and contact information next to each monitor may deter occupants from tampering with the monitors. If applicable to your building, placing this type of label or placard in multiple languages will help to ensure the labels are accessible and understood.

3.2 Monitoring period

3.2.1 Data collection, backup, and review

Throughout the monitoring period, check data periodically to make sure there are no missing data. Check with someone who is actively onsite if there are abnormal readings and keep a running log of events in specific rooms or at the building in general that may have caused these readings. If there are abnormal readings that do not have a clear explanation, try moving the monitor next to another monitor for a day to understand if the readings are high due to a technical issue with the sensor or the conditions of the room. Regularly checking the data for these types of anomalous trends will provide context when evaluating the results.

3.2.2 Notetaking for atypical events in the building or surrounding location

Document any days that the building is unoccupied, when there are severe weather events, power outages, or other major maintenance events. Any other atypical events that occur during the study period (e.g., deep cleaning, large in-person events) should be noted that might provide important context to observed data.

3.2.3 Troubleshooting

Reviewing for missing data can help actively troubleshoot during the study period. Check with someone onsite who can verify if there were Wi-Fi outages and whether the location of the monitor should be changed due to Wi-Fi access. Additionally, if it was previously determined that the number of monitors available are less than the number of rooms to be assessed, remember to move the monitors halfway through the study period to new rooms to capture more IEQ data for your site. If monitors are running into logging issues that are unrelated to Wi-Fi connection, contact the manufacturer's technical support team.

3.3 Administer survey or focus group

During the monitoring period, you will also want to conduct a focus group or survey with the building occupants to gather qualitative data to supplement your quantitative data. The performance of the building from the occupants' perspective can give you a greater understanding of the building and point toward problem areas and solutions.

3.3.1 Timing

Administering the focus group or survey in the middle of the monitoring period is good practice. This will allow enough time to have observed data trends in the building beforehand to inform the questions or target areas in the building and enough time remaining in the assessment to allow respondents a few weeks to complete the survey or focus group.

3.3.2 Recruiting participants

Recruiting participants will require coordination with the main site contact to distribute information via flyers, QR codes, emails, and word of mouth in staff meetings. Let people know what you are asking them to do, how the collected responses will be used, who will have access to the data, and how long it will take so they can prepare.

3.3.3 Technical issues

If you decide to conduct a focus group discussion, plan out the logistics of how you will conduct the discussion—whether it will be in-person, online, or hybrid. Conducting focus groups virtually can be challenging. If you are not able to be with the occupants in person, ask about the occupants' ability to join video calls and the quality of the site's internet connection. In online and hybrid formats, decide on the best and most accessible meeting platform (Zoom, Teams, etc.) for the study team and the site. It is best to have each participant on their own individual computers, laptops, or phones, as it will prevent any feedback or volume issues with multiple people speaking in the same room. It can also help for notetaking and distinguishing who is speaking. If the bandwidth is limited, video may not be possible. It is important to talk with someone at the building to learn how best to handle the logistics.

4.0 Analysis

Collecting all this data is not useful without a data analysis plan in place. The purpose of this document is to focus on the data collection process of an energy and IEQ assessment. This section provides a few high-level notes on preparing for data analysis. FEMP's Healthy Buildings and Energy Support Tool (H-BEST) is a helpful resource, but every site will have different needs and priorities, and additional graphs and tables may need to be created. FEMP’s case studies webpage provides case studies under the “Healthy Buildings” category that are a good starting point for consideration.

4.1 Data analysis preparation

The following provides some general guidelines and tips for working with the IEQ data collected from the monitors:

- **Convert timestamps for local time zone** to ensure you are working with data that are reflective of the location and the time of low or high recordings.
- **Unit conversions (e.g., °C to °F; ppb to µg/m^3)** to ensure you are working with standardized units for comparison.
- **Assigning each monitor a room/location** to identify in the produced graphs and tables.
- If collecting outdoor data, **merging the file format** with the indoor sensors to compare indoor conditions more easily with outdoor conditions.
- **Filtering out unoccupied times (e.g., nights, weekend)** and periods of abnormal occupancy to understand how occupants are being affected during the times they are in the building and rooms.
- **Creating plots and tables**, such as timeseries, box and whisker, summary tables, or other figures as appropriate.

H-BEST is one option for analysis and is an Excel-based tool for processing and graphically representing IEQ data. The tool produces a report that summarizes the findings and provides recommendations for improvement.

If the data analyst on your team has the skills and interest, other graphs such as timeseries or boxplots can be produced beyond what H-BEST provides and can be computed in your software or language of choice, such as MATLAB, R, or Python. The data can be grouped by room, HVAC zone, perimeter/core, orientation (north, east, south, west), etc. These can help to identify targeted solutions for the building.

4.2 Improvement recommendations

Appendix F contains a sample of common improvement recommendations relating to energy and IEQ with guidance and additional information.

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Appendix A – Example Remote Training Slides

Agenda

- **Overview of the Pilot Study**
  - School commitment
  - Energy Star Portfolio Manager (David
- **Assessment Tools**
  - Equipment overview
  - Deployment and logger placement considerations
- **Logger Set-Up**
  - Equipment set-up steps for Awair and PurpleAir loggers
- **Next Steps and Discussion**

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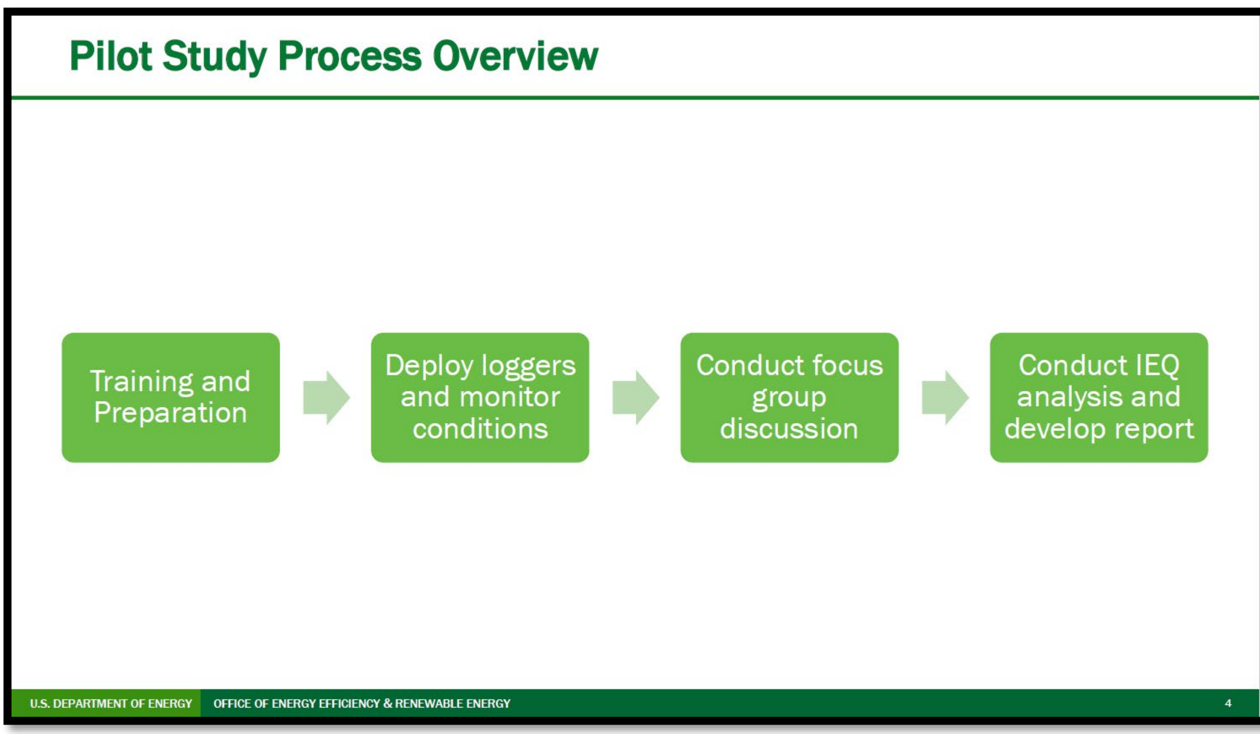
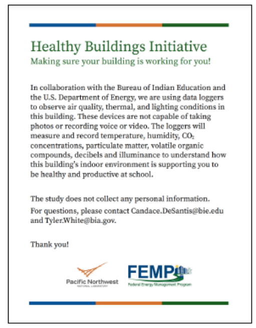


Staff Focus Group and Community Letter

- Focus group
  - How air quality, thermal conditions, lighting, and sound impact students and staff
- Community notification (Optional)
  - A community letter for the school to distribute as needed
  - Informational flyers to post at the school

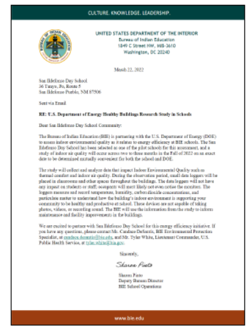


Healthy Buildings Initiative
Making sure your building is working for you!

In collaboration with the Bureau of Indian Education and the U.S. Department of Energy, we are using data loggers to observe air quality, thermal, and lighting conditions in this building. These devices are not capable of taking photos or recording voice or video. The loggers will measure and record temperature, humidity, CO_2 concentrations, particulate matter, volatile organic compounds, decibels and illuminance to understand how this building's indoor environment is supporting you to be healthy and productive at school.

The study does not collect any personal information.
For questions, please contact Candace.DeSantis@bie.edu and Tyler.White@bia.gov.

Thank you!



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Awair Omni Deployment

- **Place monitor on a surface about 3 to 6 feet high to be generally chest or head level of a seated or standing occupant.**
  - Be sure none of the air intakes are blocked on the sensor. Use the clip to stand up if needed.
- **Deploy in locations representative of what occupants will experience regularly.**
  - Consider effects of temperature, such as proximity to a heater, vent, or window.
  - Consider effects of airflow, such as operable windows, air filters, and air diffusers.
- **Do not place loggers where they will interfere with daily activities of occupants.**

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PurpleAir Deployment

- **Install PurpleAir within 15 feet of a power outlet and ideally within range of the Wi-Fi network.**
- **Mount logger in a location away from:**
  - Exhausts/vents
  - Local sources of direct pollution
  - Any foliage that would increase likelihood of insects getting inside the unit
  - Student interference (bouncing balls)

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Deployment Next Steps

- **Logger Placement Photos**
  - Zoomed out photos showing classroom from multiple angles)
  - Record room number for each logger
  - Record date and time of deployment
  - Send information to
- **Schedule weekly 30-minute check-in meeting series for troubleshooting (OPTIONAL)**
  - Include key site member(s) who will be responsible for assisting with equipment

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Appendix B – Survey and Focus Group Questions

The following provides example focus group questions used in past assessments for FEMP that are more targeted for the types of IEQ assessments performed at federal buildings:

- What is your role, and which room(s) do you typically work in?
- How would you describe the temperature of your workspace?
- Overall, does the temperature in your workplace interfere with the working/learning environment?
- Are there any seasons or time of day where you most commonly experience discomfort with the temperature in your workspace?
- Are all doors metal?
- How would you describe the indoor air quality of your workspace?
- Overall, does the indoor air quality in your workplace interfere with the working/learning environment?
- Do you have the ability to open a window to let in fresh air? If yes, do you open your windows for ventilation?
- Do you have HEPA filters or any other portable air purifying devices in your workspace?
- What is your experience from using the portable air purifying devices? Are they operating all day?
- How much time in between replacing the devices? Once a year, once every five years?
- Are they noisy?
- How would you describe the level of background noise (e.g., from outside, other classrooms, HVAC equipment) in your workplace?
- Overall, does the noise level in your workspace interfere with the learning environment?
- How would you describe the lighting in your workspace? Do you find it to be too dim, too bright, or just right?
- Do you have any issues with the lighting in your workspace, for example, are there automatic lights that turn off, issues with flickering, unpleasant light colors (e.g., too warm/red, too cool/blue), or glare?
- Do you have windows that let in daylight? Do you tend to keep the blinds open or closed?

Example survey questions used in past assessments for FEMP include:

- Please indicate your typical level of comfort in each room as a result of the temperature. Consider your own preferences as well as comments from occupants to the best of your knowledge. Respond based on your experience in the previous one month. Please select not applicable if you are not familiar enough to comment on the space.

  - Uncomfortably cold
  - Slightly too cold
  - Comfortable
  - Slightly too hot
  - Uncomfortably hot
  - Not sure/not applicable

- Please indicate your typical level of comfort in the building generally as a result of the temperature for each season. Consider your own preferences as well as comments from occupants to the best of your knowledge. Please select not sure/not applicable if you do not work during that season, have not worked during that season yet, or do not remember.
  - Uncomfortably cold
  - Slightly too cold
  - Comfortable
  - Slightly too hot
  - Uncomfortably hot
  - Not sure/not applicable
- Please provide any comments or clarifications to the first two questions.
- Please indicate which of the following air quality issues impacts comfort in each room. Select all that apply. Please select not applicable if you are not familiar enough to comment on the space.
  - Foul odor
  - Stuffiness
  - Too dry
  - Draftiness
  - Too humid
  - Dust or allergens
  - Scents from chemicals, perfumes, or cleaning products
- Not applicable
- Please indicate your typical level of satisfaction in each room as a result of the background noise (e.g., from outdoors, other classrooms, HVAC equipment). Consider your own preferences as well as comments from occupants to the best of your knowledge. Respond based on your experience in the previous one month. Please select not applicable if you are not familiar enough to comment on the space.
  - Satisfied

  - Slightly dissatisfied
  - Dissatisfied
  - Not applicable
- Please provide any comments or clarification to the previous question here.
- Please indicate the typical level of satisfaction in each room as a result of lighting, both the overhead lights and daylight. Consider your own preferences as well as comments from occupants to the best of your knowledge. Please select not applicable if you are not familiar enough to comment on the space.
- Please provide any comments or clarifications to the previous question here. Please comment on any uncomfortable lighting effects (e.g., automatic lights that turn off, issues with flickering, unpleasant light colors, glare) and note which room(s) you are referring to in your response.
- Please provide any additional comments concerning your satisfaction or impacts to the occupant's working/learning environment as a result of the indoor environment. Please also provide any complaints you have heard from students, making sure not to include any identifying information.

Appendix C – Building Information Walkthrough Form

Please answer the following questions to help contextualize the indoor air quality data that will be collected over the next few weeks and identify solutions.

If you encounter any questions which you are unsure of the answer, simply note "unsure" in the answer field.

Site
Site name:
Occupancy
What is the maximum typical occupancy at any given time?
Which days of the week and times of day are the site occupied?
Note any holidays and other planned site closures during the study.
For each room being monitored, please note approximately the largest number of people that use the room regularly.
Lighting
Lighting type(s) used (e.g., compact fluorescent, fluorescent, LED, incandescent).
In general, how often are overhead light fixtures cleaned and dusted?
Approximately how many years ago, on average, were the current light bulbs most recently installed or replaced?
Please note if any of the rooms monitored have window treatment to prevent glare, such as blinds, curtains, or construction paper.
Heating, Ventilation, and Air Conditioning
For each air handler unit, please provide the following information:
(1) The main rooms or areas served by this unit?
(2) Is there an outdoor air supply and, if known, what is the supply rate (CFM or CFM per sf or per person)?
(3) If applicable, what is the position of the air damper? Is it controlled by the BAS or fixed?
(4) If applicable, is there a filter? What is the MERV listed? How often is it replaced, approximately?
Are there in-room air purifiers or other mechanical filtration or sanitization features in the building(s)? If so, please include the make, model, and filter rating, and for in-room purifiers, the number of purifiers.
What is the typical HVAC schedule of operation for each room or zone? Do the systems run at night and over weekends?

Appendix D – ENERGY STAR Portfolio Manager Questions

The answers to the following questions are required inputs for ENERGY STAR Portfolio Manager.

- What year was the site built?
- What is the total gross floor area of the site, in square feet?
- What is the total irrigated area of the site campus, in square feet?
- What is the current occupancy level of the site (in % of maximum)?
- What is the total number of buildings at the site?
- What is the total number of staff/workers?
- Is the site operated on the weekend?
- Does the site have cooking facilities?
- What percent of the site area is heated?
- What percent of the site area is cooled?
- What is the total student seating capacity?
- How many months per year is the site occupied?
- How many computers does the site have?
- What is the gross floor area used for food preparation?
- How many walk-in refrigerator/freezer units does the site use?
- What is the floor area of the gymnasium (if applicable)?
- What is the name of the school district (if applicable)?

Appendix E – Example Template for Monitor Comparison

Device	Monitor 1	Monitor 2	Etc...
Company	Company 1	Company 2	
Link			
Intended User	Consumer	Researcher	
Pricing			
Per device	$500	$1,000	
Annual subscription	$1,500	$75	
Metrics			
Temperature	X	X	
Relative Humidity	X	X	
CO_2	X	X	
$PM_{2.5}$	X	X	
TVOC		X	
Light (lux)			
Sound (decibels)			
Other	Formaldehyde		
Data Storage & Transfer			
Frequency	1 minute	1 minute	
Upload data via Wi-Fi	Yes	Yes	
Upload data via cellular	No	No	
Storage	10 MB	None	
User Experience			
Usability	Easy to download data from local storage	Easy to set up via mobile app	
Online dashboard	Yes	Yes	
Apps	None	Required to set up	
Customer Support	Very responsive to emails	Did not respond to email request for info	
Maintenance			
Calibration	Pre-calibrated with certificate	Pre-calibrated but requires cartridge replacement every 2 years	
Power and Battery	USB-C power cord; 10 hours battery	USB-C power cord; 4 hours battery	
Lifetime	5 to 7 years	3+ years	
Sensing			
Temperature			
Measuring range	-20 - 100 °C	-40 - 125°C	
Output resolution	0.01 °C	0.015°C	
Accuracy	±1 °C	±0.2°C	

Humidity *Measuring range* *Output resolution* *Accuracy*	 0 - 99 % RH 0.01 % RH ±5 % RH	 0 - 100%RH 0.01%RH ±2%RH	
CO_2 *Measuring range* *Output resolution* *Accuracy*	 400 to 2,000 ppm 1 ppm ±3 % m.v. ±50 ppm	 400 - 5,000 ppm 1 ppm ±75 ppm and ±10%	
$PM_{2.5}$ *Measuring range* *Output resolution* *Accuracy*	 0 to 1,000 µg/m³ 1 µg/m³ ±10 % (<30 µg/m³: ±3 µg/m³)	 0 - 1000 µg/m³ 1 µg/m³ ±15 µg/m³ or ±15%	
TVOC *Measuring range* *Output resolution* *Accuracy*	 0 - 60000 ppb 1 ppb ±15 % ±8 ppb	 0 - 60000 ppb 1 ppb ±10%	
Ambient Light *Measuring range* *Output resolution* *Accuracy*		0.96 to 64,000 Lux	
Ambient Noise *Measuring range* *Output resolution* *Accuracy* *Sensitivity* *Signal to Noise Ratio*	 -20 - 100 °C	 -26 dBFS 61.5 dB(A) -40 - 125°C	

Appendix F – Recommendation Measures

Improvement Measure	IEQ Metrics	Issue and Solution	Guidance	ECM
Ventilation setbacks and scheduling	Carbon Dioxide	There is room for improvement in CO_2 readings during certain hours of the day/week. Set up a schedule to increase the outdoor air supply during these times specifically.	Set up ventilation schedule so that the outdoor air damper changes position to let in more outdoor air according to times that CO_2 is regularly high. If there is not a modulating air damper, it is a good idea to install one as it is an important feature to control air quality and energy use. Check to see the impacts to indoor CO_2 levels to find what the right position is for different times. Letting in more outdoor air could increase particulate matter if there is poor outdoor air quality or insufficient air filtration at the air handler. Also examine the IEQ data to see which times during a typical week the ventilation rate could be reduced from current levels when CO_2 is good in order to save energy.	
Configure demand-controlled ventilation (DCV)	Carbon Dioxide	There is room for improvement in CO_2 readings during certain hours of the day/week. DCV can mitigate this by increasing ventilation when there is high occupancy/CO_2 and also save energy by reducing ventilation when occupancy is low.	DCV uses feedback from IAQ sensors to adjust the ventilation rate or outdoor air damper position to provide more outdoor air when occupancy is high and reduce the outdoor air when occupancy is low to save energy. This measure will require installation of reliable return air or on-floor CO_2 sensors if they do not already exist. Note that CO_2 sensors can be notoriously faulty and will require periodic calibration. It is important to place the sensors in spaces where there are occupants, not in the air return, to capture what the occupants are experiencing. Implement a fault tolerant strategy—do not implement a strategy that would drive the outdoor air dampers to 0% or 100% indefinitely.	Re-tuning
Re-tune HVAC controls and sensors	Carbon Dioxide	There is room for improvement in CO_2 readings. Malfunctioning of the controls and sensors for the ventilation system could be a reason why the CO_2 levels are higher than expected.	First check to see if the ventilation system was designed to meet to occupancy of the building. If occupancy has increased over time, or if the ventilation rate was not established through occupancy calculations, then the ventilation rate may need to be redesigned. Otherwise, there could be an issues with the controls or sensors causing the ventilation rate to be too low. Test and calibrate any sensors used to control ventilation rate, such as CO_2 sensors and airflow damper position sensors. CO_2 sensors should be in occupied spaces. Sensors in zone-level return air may not give accurate readings of what the occupants are experiencing.	Re-tuning

Improvement Measure	IEQ Metrics	Issue and Solution	Guidance	ECM
Test and balance HVAC system for air circulation	Carbon Dioxide, TVOC	There is room for improvement for CO_2 or TVOC readings. Testing or verifying functionality of the ventilation system can be a quick first step to identify problems before investing in more costly solutions.	It is important to test the HVAC/ventilation system every five years to verify functionality of air distribution. Having a high-performing ventilation rate is wasting energy if the air is not distributed effectively through spaces to reach occupants. If the static fan pressure gets to be too low or the distribution nozzle type/damper position limits flow too much, the air will not be discharged at a velocity to facilitate effective air distribution. There could also be furniture or objects obstructing the air flow into the space. Improve air distribution by removing obstructions blocking diffusers and/or changing diffuser type or setting (increasing air velocity) or increasing fan speed so that air can circulate better throughout space. Note that if the air velocity is too high, it can affect the thermal comfort of occupants (making them feel too cold).	Audit template
Increase outdoor air supply	Carbon Dioxide, TVOC	There is room for improvement for CO_2 or TVOC readings. Increasing the ventilation rate will improve CO_2 and TVOC levels.	Re-tuning and testing the HVAC system are important activities to do before increasing the ventilation. However, if the ventilation rate was not designed to meet the occupancy of the building, it will be important to at least increase to acceptable levels or, even better, to high performance. This is a good solution if there are consistently elevated TVOC or CO_2 levels, which could signify the occupancy is higher than the design (CO_2 from occupants breathing and VOCs from indoor materials or occupants' clothing and perfumes). Determine the typically maximum occupancy of the building and then set the outdoor air fraction to 30-60% above ASHRAE 62.1, ASHRAE 170, or other applicable standard. This measure can be accompanied with energy savings features like night and weekend setbacks or DCV. Note that this could bring in more outdoor particulate matter if outdoor levels are elevated, so ensure that filters have a good MERV and are well maintained.	

Improvement Measure	IEQ Metrics	Issue and Solution	Guidance	ECM
Replace or upgrade the air handler unit (AHU)	Carbon Dioxide	There is significant room for improvement for CO_2. Depending on state and quality of existing ventilation equipment, upgrading could improve the ability of the HVAC system to meet its load and have finer control over the air quality.	This is an applicable measure if the AHU, including rooftop terminal unit (RTU), packaged units, and packaged terminal units, is reaching the end of its lifespan or in poor condition. The system may no longer be able to meet ventilation requirements of the building, either due to declining performance of the system or changes in occupancy over time. Replace the AHU with a high-performance, energy-efficient model. This measure will have a high capital cost, but if the system will need to be replaced in the near future anyway, selecting a higher performing model may make financial sense.	Audit template
Install a dedicated outdoor air supply (DOAS)	Carbon Dioxide, TVOC	There is significant room for improvement for TVOC or CO_2 readings. If thermal comfort is good, that may mean the HVAC system is prioritizing thermal comfort over adequate ventilation. A solution is to decouple heating/cooling and ventilation with a DOAS.	Consider adding a DOAS to the zone(s) with high CO_2. The DOAS can be an expensive option but an energy-efficient solution.	
Install economizer	Carbon Dioxide	This is significant room for improvement for CO_2 readings. Economizers provide more outdoor air when outdoor temperatures are amenable and less when outdoor temperatures become more extreme.	If the IEQ data collected was during a shoulder season (spring, fall), then this solution will be more applicable because economizers are most effective in temperate outdoor conditions. Include a minimum outdoor airflow rate in the controls during occupied hours so that sufficient ventilation is always supplied to the building when occupied. Regularly check the performance of the outdoor air temperature sensors and calibrate accordingly so that economizers can operate as intended. This measure should reduce heating and cooling energy.	Audit template

Improvement Measure	IEQ Metrics	Issue and Solution	Guidance	ECM
Upgrade to MERV 13 filters and clean/replace regularly	Particulate Matter	There is room for improvement in particulate matter readings. High particulate levels could be from outdoor air, especially if the building is in a polluted area (e.g., near highway, factory, urban center, wildfire prevalent zone). Better performing filters will reduce the amount of these particulates that enter the building.	MERV is a characteristic of an air filter, with high rating values signifying the ability to filter out more and smaller particulates. Enact procedures in the building to purchase MERV 13 filters and establish a maintenance schedule to replace regularly. Notice the level of dust and dirt on filters when replacing and establish a schedule to replace the ones that get dirty more frequently. Dirty filters can increase static pressure, which will either reduce the amount of air that is able to be supplied to the building or use more energy to supply the same amount of air.	O&M
Balance HVAC pressure to slightly positive	Particulate Matter	There is room for improvement in particulate matter readings. It is possible that outdoor particulates are bypassing the air filtration and entering through leaks in the envelope. Increasing the fan pressure until there is positive pressure will prevent outdoor air from entering through the envelope.	This solution is applicable if the building experiences negative pressure (i.e., the air flows from outside to inside). Confirm this by opening an exterior door and noticing if the air tries to flow in the building. Make the pressure slightly positive by increasing the static pressure of the ventilation fans until air tends to flow outwards. This could improve thermal comfort as well by reducing drafts. Reducing infiltration could also increase CO_2 levels because there will be less outdoor air entering the building.	Re-tuning
Seal envelope to decrease infiltration	Particulate Matter, Thermal Comfort	There is room for improvement in particulate matter readings. It is possible that outdoor particulates are bypassing the air filtration and entering through leaks in the envelope. Sealing the envelope will prevent the amount of air that infiltrates the building.	This solution is applicable if the building experiences negative pressure (i.e., the air flows from outside to inside). Confirm this by opening an exterior door and noticing if the air tries to flow into the building. Sealing the envelope will reduce the amount of infiltration, which may be a source of particulates. This could improve thermal comfort as well by reducing drafts and save energy by reducing heating and cooling loads. Reducing infiltration could also increase CO_2 levels because there will be less outdoor air entering the building.	Audit template, O&M

Improvement Measure	IEQ Metrics	Issue and Solution	Guidance	ECM
Install direct exhaust system	Particulate Matter	There is significant room for improvement in particulate matter readings. A direct exhaust system is effective at removing particulate matter and other air pollutants from a specific room or location.	This measure is most effective if there are high particulate matters in a specific room or space but other locations in the building are performing well. This may be more expensive and energy intensive than other measures, so use as a last resort. This measure is applicable to any room with high particulate levels, but is often used when dedicated exhaust is not available for kitchenettes, maintenance rooms, rooms with paint and chemical usage, or high volume, dedicated printer rooms.	
Enact a green cleaning policy	TVOC	There is room for improvement in TVOC readings and according to the diagnostic information, cleaning products are a potential source of VOCs in the building. Mandating the use of green cleaning products could reduce the observed spikes in TVOC.	Most conventional cleaning products contain VOCs and even with a high-performing ventilation, this can still cause temporary, large spikes in VOCs. Create a policy to only use certified, low-emitting cleaning products. Look to see if the TVOC spikes are observed at intervals that could correspond to cleaning crew activities.	Audit template, Policy
Conduct a building flush out	TVOC	There is room for improvement in TVOC readings and according to the diagnostic information, indoor materials are a potential source of VOCs. If there has been furniture, paint, carpet, sealants, or other materials installed in the building in the past 1-2 years, they could be contributing to the TVOC levels. Flushing out the building will help to off-gas these materials so they are no longer emitting high levels of VOCs.	To address potentially high-emitting materials and furniture, flushing out the building after the installation of new furniture, partitions, carpet, paint, or other finishes will reduce the VOC concentration of these materials. Lock the outdoor air damper to 100% and run the ventilation for two to three days. If the building is unoccupied during this period, the outdoor air does not need to be conditioned to the same extent to save heating or cooling energy; for example, the temperature setpoints could be set to 60–80°F. Be sure that the indoor temperature and humidity return to a more comfortable range before occupancy returns. This could be done during a shoulder season (spring or autumn) to further reduce energy use.	Audit template, O&M

Improvement Measure	IEQ Metrics	Issue and Solution	Guidance	ECM
Replace or remove potentially emitting materials	TVOC	There is significant room for improvement in TVOC readings and according to the diagnostic information, indoor materials are a potential source of VOCs. If there has been furniture, paint, carpet, sealants, or other materials installed in the building in the past 1-2 years, they could be contributing to the TVOC levels. Removing or replacing these materials will mitigate this issue.	In general, conventional materials can continue to off-gas VOCs for up to one to two years after installation. One solution, although potentially more expensive, is to remove or replace the sources. If these materials are replaced, ensure that the new materials are certified low emitting according to LEED v4 Low Emitting Materials credit, WELL Standard feature 4 VOC reduction feature, or BIFMA e-3 Low Emitting Furniture Prerequisite.	
Replace or upgrade heating and/or cooling system	Temperature	There is significant room for improvement for temperature and significant dissatisfaction with temperature from the occupant survey. Depending on state and quality of existing equipment, upgrading could improve the ability of the HVAC system to meet its load and have finer control.	This measure is most effective when current systems are either undersized to meet load or oversized with insufficient capability to modulate to observed loads. Upgrading to a modern, energy-efficient system with the capacity to support the thermal load of the building could save energy and improve temperature.	Audit template
Ensure placement and calibration of temperature sensors and adjust temperature setpoints	Temperature	There is room for improvement for temperature readings and satisfaction with temperature from the occupant survey. Temperature sensors used to control the HVAC may be faulty or not placed in a location where the occupants are working. Ensuring the performance (calibration, placement) of these sensors is an important first step before adjusting temperature setpoints to create a more comfortable thermal environment.	Check that the sensors are accurately reading values and that they are placed to measure as close to what the occupants in that space are experiencing as possible (e.g., on walls around chest height is better than a return duct). Once the sensor a providing accurate readings, adjust the temperature setpoint until the spaces are conditioned to the desired range. If there is a lot of variation of temperature within zones, it will be prudent to provide another solution to add greater temperature control, such as distributed fan coil units or variable air volume (VAV) units. A lower cost solution could be enacting a hoteling policy so that occupants can choose the spaces that meet their comfort needs or providing thermal control devices to occupants. Fixing faulty or poorly placed sensors can have a big impact on occupant comfort and save energy if the building is being over conditioned because of the sensors.	O&M

Improvement Measure	IEQ Metrics	Issue and Solution	Guidance	ECM
Add window films	Temperature	There is room for improvement for temperature readings and complaints of too warm on the occupant survey. Check to see if the low-performing temperature readings tend to be because of too warm in perimeter spaces. Window films can reduce the solar heat gain coefficient of glazing, improving thermal comfort near envelope.	A risk of excess daylight penetration is occupant discomfort and increased HVAC loads. Window treatments may be used to help prevent this by reflecting radiant heat while still letting most visible light pass through. Consider south facing windows first, which are more likely to have a high solar heat gain. Window films inadvertently decrease the visible light transmittance a small amount, so ensure that daylighting is not compromised.	Audit template
Increase envelope insulation	Temperature	There is significant room for improvement for temperature readings and there are significant complaints of too warm in the summer and too cold in the winter from the occupant survey. Insulation will help reduce temperature variations near the envelope.	If the insulation for the building was not designed to be high performing for the climate zone, this could be causing thermal comfort issues near the perimeter and causing the heating and cooling systems to consume more energy. Foam insulation can be injected into walls if there is physical space for a lower cost retrofit, otherwise the walls can be retrofitted and the insulation replaced. It is important that the envelope is well sealed and thermal bridging in window frames is reduced to not sacrifice the benefits from the insulation.	Audit template, O&M
Seal/caulk envelope and insulate thermal bridges	Temperature	There is room for improvement for temperature readings and complaints of too warm in the summer and too cold in the winter from the occupant survey. Sealing/caulking the envelope and insulating thermal bridges will help reduce the temperature variations near the envelope.	Sealing or caulking the envelope will reduce drafts and leaks in the envelope insulation. It is an important first step before adding more insulation to the envelope, as it is less expensive. Thermal bridging occurs when metal, usually in window frames, is not properly insulated, allowing heat to transfer more easily between the outdoors and indoors. This can sacrifice the performance of high-performance windows and walls.	Audit template, O&M

Improvement Measure	IEQ Metrics	Issue and Solution	Guidance	ECM
Upgrade windows/glazing	Temperature	There is significant room for improvement for temperature readings and complaints of too warm in the summer and too cold in the winter from the occupant survey. Upgrading the windows to have better insulation properties will help reduce temperature variations near the envelope.	Windows are often the source of greatest heat transfer in a building envelope, having much lower insulation than walls and roofs. Many modern buildings have large glass facades, which can have significant effects on thermal comfort and energy consumption if they are not high performing. Insulation is given in the R-value or U-value of an envelope component, with high R-value or lower U-value indicating better insulation. Replacing windows/glazing with low-emissivity, double- or triple-paned, and higher R-value/lower U-value will improve thermal conditions at building perimeter and can have significant energy savings as well.	Audit template
Add enhanced dehumidification	Humidity	Humidity readings are too high. Adding a dehumidification system to the supply air will reduce the humidity levels in the respective zones.	High indoor humidity can occur in humid climate zones, especially in the summertime. Most buildings that do not control for humidity in the air supply will find a relationship between indoor and outdoor humidity levels. It should be noted that humidity levels may not always be high, for example in other seasons, so this measure should be accompanied with a shut-off control to prevent indoor humidity levels from falling below 40%.	Audit template
Install energy recovery system (ERV)	Humidity	Humidity readings are too low. Returning water vapor from exhaust air to the supply air with ERV is an efficient solution to humidify the supply air in dry climates.	Energy recovery will capture the latent heat (moisture), as well as sensible heat, from exhaust air and return it to the space. This will help to humidify the supply air if the outdoor air is dry, as well as save energy by reducing the amount of thermal condition required for the supply air. The exhaust air could be mixed directly with the outdoor air to recover the heat and moisture, or it could be done through a heat exchanger so that the exhaust air does not mix with the incoming outdoor air.	Audit template
Humidify supply air	Humidity	Humidity readings are too low. Installing a humidification system in the supply air intake can resolve this issue.	This is an alternative solution to energy recovery. Install a system that directly adds water vapor to the supply air. This can be coupled with a control device that shuts off the humidification when the humidity sensors in occupied spaces are in the desired humidity range. Note that this system will be an additional maintenance burden for building staff.	Audit template, Design
Enact hoteling policy and guidance	Temperature	There is not much room for improvement for temperature readings, but there is dissatisfaction with temperature from the occupant survey. Allowing occupants to	Everyone has somewhat different preferences for the optimal thermal environment. If the building is providing temperature, humidity, and airflow that is generally considered acceptable, hoteling or hotspots are a solution to allow occupants to choose their own location. There should be some variation in temperature through open office spaces for this to be an	Audit template, Policy

Improvement Measure	IEQ Metrics	Issue and Solution	Guidance	ECM
		hotel or hotspot (i.e., select a different workstation each day based on their preferences) will allow occupants to find a location that suits their needs.	effective solution. It will be important to educate occupants about the benefits of choosing their workspace and making it clear that the intention is for them to find a comfortable work location. Displaying the temperature and humidity throughout building spaces or even in the workplace reservation system is a transparent way for occupants to know what the thermal conditions are upfront. Some people prefer to have a dedicated workstation and work better that way, so providing an option for some employees may be important.	
Provide personal control devices and guidance	Temperature	There is not much room for improvement for temperature readings, but there is dissatisfaction with temperature from the occupant survey. Providing occupants with thermal control devices can help those who are unsatisfied feel comfortable.	Everyone has a somewhat different preference for the optimal thermal environment. If the building is providing temperature, humidity, and airflow that is considered generally acceptable, establishing a system where occupants can obtain personal thermal control device, such as seat heaters, desk fans, etc., will help improve satisfaction. Occupants should be made regularly aware that this is an option for them and educated on how to properly use the devices.	Audit template, Policy
Clean/repair overhead light fixtures	Horizontal Illuminance	There is room for improvement for horizontal illuminance readings, occupants complain of too dim, and there is general dissatisfaction with electric lighting. Depending on the state and quality of existing lighting, cleaning and repairing could increase illuminance.	Note the age and lifespan of the overhead lights in the building if that information is available. If the overhead lighting fixtures have not been cleaned and maintained in several years and there are issues with overhead lighting being too dim, cleaning dirt and dust off fixtures may have a significant impact to horizontal illuminance levels. Some bulbs may be dead and need to be replaced. This is a relatively inexpensive solution and a good first attempt at achieving the target illuminance levels and improve perceived brightness.	Audit template
Install overhead light diffusers	Horizontal Illuminance	There is room for improvement for horizontal illuminance readings, occupants complain of too bright or uncomfortable glare, and general dissatisfaction with electric lighting. Diffusers may eliminate intense light levels, leading to	A light diffuser is any transmissive material placed in the path of a light source that causes light to spread equally in all directions. For overhead lighting, a diffuser is a decorative panel, or translucent film, that fits on or above existing light fixtures to diffuse directional, concentrated lights. There are two common styles of workspace lighting: prismatic and parabolic.	Audit template

Improvement Measure	IEQ Metrics	Issue and Solution	Guidance	ECM
		improved visual comfort and satisfaction.		
Upgrade to LED overhead lighting	Horizontal Illuminance	There is room for improvement for horizontal illuminance readings, occupants complain of too dim, and general dissatisfaction with electric lighting. Replacing existing fluorescent or incandescent fixtures with LED luminaires designed to meet target illuminance could improve occupants' visual comfort and reduce energy use.	Upgrade overhead to LED light fixtures and design to target of 400 lux at desk level. Light fixtures should be spaced to provide even lighting throughout workspaces. Sudden changes in lighting conditions often cause temporary dissatisfaction until occupants adjust. LED light systems have the ability to integrate with advanced solid state lighting features, such as color and illuminance tuning, daylight controls, and occupancy sensors.	Audit template
Change interior materials to light-toned, reflective colors	Horizontal Illuminance	There is room for improvement for vertical or horizontal illuminance readings, occupants complain of too much contrast, and general dissatisfaction with electric lighting. Replacing dark surfaces with lighter tones can give a brighter work environment and reflect more light into occupants' eyes as they are working at computers, which could make occupants feel more alert and productive.	Replace dark-toned interior materials with lighter-toned, more reflective alternatives. Surfaces should be diffuse/matte, as glazing/shiny surfaces can reflect more light but also cause glare. Dark color tones (e.g., grays, browns, blues) for interior materials, such as the ceiling, floor, walls, and furniture, can absorb light and can create contrast and a dim lighting environment that may not be conducive to office work. It is important to have consistency throughout spaces to prevent sharp contrast and provide lighting uniformity.	Audit template, Policy

Improvement Measure	IEQ Metrics	Issue and Solution	Guidance	ECM
Provide local task lighting	Horizontal Illuminance	There is room for improvement for horizontal or vertical illuminance readings, some occupants complain of too dim, and others complain of too bright, and general dissatisfaction with electric lighting. Task lighting gives occupants control of their lighting environment to improve visual comfort.	Provide task lighting, such as desk lamps, to workstations in zones that are under-illuminated or to occupants that are dissatisfied with their lighting conditions. Task lighting increases the horizontal illuminance so that occupants are visually comfortable. Task lighting could be wall sconces on a vertical surface to improve vertical illuminance and help with ambient lighting conditions. Excessive dimming of LEDs may cause flickering, which could be uncomfortable for some occupants.	Audit template, Systems
De-lamp/tuning overhead lights	Horizontal Illuminance	Horizontal illuminance levels are high and there are complaints of lights being too bright. De-lamping or dimming overhead lights could improve satisfaction and save energy.	If overhead lighting is dimmable/tunable, reduce the illuminance levels until they measure 400 lux at workstations. If not, de-lamp bulbs as evenly as possible to reach the 400-lux target. If there are some complaints in the occupant survey of too dim, or the de-lamping causes unevenness in the illumination in a space, provide task lighting to meet preferences.	Re-tuning
Reduce partition height or install translucent or transparent wall sections	Horizontal Illuminance	There is room for improvement for vertical or horizontal illuminance readings, there is unsatisfaction with daylight availability, and the majority of cubicles cannot be seen over. Reducing the partition height will allow light to penetrate farther into open office spaces. Adding transparent partitions will allow light to penetrate farther into open office spaces.	Reduce partition height to below eye level to increase vertical illuminance and horizontal illuminance to improve the visual environment if conditions are too dim. If it is suspected that acoustics may be an issue (sound from conversations and phone calls carrying through the space), a better option could be to install glass partitions at occupants' head level while seated and above. If it is suspected that occupants may value privacy, a better option is to make translucent, instead of transparent, wall sections where light can penetrate but neighbors cannot see through the frosted glass. If there are enclosed offices around the perimeter that block daylight from entering interior office spaces, install translucent or transparent walls or sections of walls to all occupants to have access to daylight.	Audit template, Policy

Improvement Measure	IEQ Metrics	Issue and Solution	Guidance	ECM
Install light shelves	Horizontal Illuminance	There is room for improvement for vertical or horizontal illuminance readings, and there is unsatisfaction with daylight availability,	A method for increasing daylight in the workplace is the use of light shelves. Light shelves are horizontal elements placed on the interior or exterior window wall to increase the reflectance of daylight into a space. The shelves are installed higher on the window and are an effective tactic for increasing the daylight exposure in the workplace. If combined with daylight harvesting techniques (automatic dimming of perimeter lighting when there is sufficient daylight available), this measure can have lighting energy reductions.	Audit template, Policy
Install color-tunable LED overhead or task lighting	Circadian Stimulus	There is room for improvement for circadian stimulus readings, and there is dissatisfaction with daylight availability. Color-tunable lighting (overhead or task) can provide occupants with greater circadian stimulus.	If access to daylight via windows is not a feasible option, LED white-tunable light can be used to support proper circadian functioning by providing blue light during the day and warmer-toned light after dark. If the lighting is not automatically tuned or put on a timer, this technology will require user education on its operation and importance, or there is a significant risk that the occupant will not receive the full benefits of the lighting solution. LED tunable lights have a higher initial cost than fixed-white LED light sources or conventional sources, largely because of their complex nature. In addition, the wiring for LED tunable lighting systems is more complicated. Tunable LEDs have lower efficacy (lumens per watt) compared to fixed-white LED bulbs, but may have a higher efficacy compared to conventional light sources.	Audit template
Modify perimeter desk orientation to be perpendicular to windows	Glare	Occupants complain of glare from daylight. Positioning desks to be perpendicular to windows can help improve this.	Users of computer screens facing an exterior window may experience contrast issues or glare from direct sunlight, while users of computer screens facing away from an exterior window may experience difficulty viewing computer screens. Orient desks perpendicular to glare sources when possible. This is a low-cost, good first step solution to reduce the effects of glare, but depending on how severe the issue is, it may not be enough.	Audit template, Policy

Improvement Measure	IEQ Metrics	Issue and Solution	Guidance	ECM
Install automated shades or electrochromic glass for open office areas	Glare	Occupants complain of glare from daylight. Adding automated shades or electrochromic glass, which can adjust based on the time of day or amount of light is an effective way to mitigate this issue.	Electromatic glass can automatically adjust its tint to prevent glare from windows and automated shades can close when sensors detect excessive light. Especially in open areas where a few occupants share a window or in conference rooms, manual override of the automated settings is important to give users control of their space. Make it clear if occupants are allowed to modify the shades and how to do so effectively. If there are not already user-operable shades in exterior enclosed offices, it is important for occupants to be able to control for glare. This measure can help reduce heat gain in summer and save energy. Electrochromic glass requires fenestration replacement and is a much more expensive alternative compared to automated shades.	Audit template, Policy
Install daylighting controls/daylight harvesting	Glare	Occupants complain of glare from daylight. Lighting controls will turn off electric lighting when there is sufficient daylight, which could reduce stress from over-illumination and glare.	Install lighting controls to the light fixtures near perimeter windows with photosensors so that the overhead lights can be dimmed or turn off when there is sufficient daylight in the space. This will only have a moderate effect on glare compared to other measures, but will reduce lighting energy use.	Audit template

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