

# Healthy Building Initiative (HBI) Program Training Slides

**Pacific Northwest National Laboratory**

July 2020



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# Overview

# HBI Toolkit Overview

- The HBI toolkit contains resources that facilitate decision making relating to building upgrades that promote energy efficiency and occupant productivity.
- This training document is intended to guide HBI users to collect data, enter it into the accompanying HBI Excel Tool, and interpret the results.
- The results are twofold:
  1. *Quantitative Benefits* – the HBI Excel Tool will calculate the financial gains relating to productivity improvement of occupants as a results of improving thermal comfort, lighting, and indoor air quality. This can be compared to energy and capital cost of upgrades if provided by user.
  2. *Customized Improvement Recommendations* -- based on the building data and information provided, the HBI Excel Tool will return suggestions for operational modifications and equipment upgrades to improve indoor environmental quality (IEQ).

# HBI Background

## Value Propositions

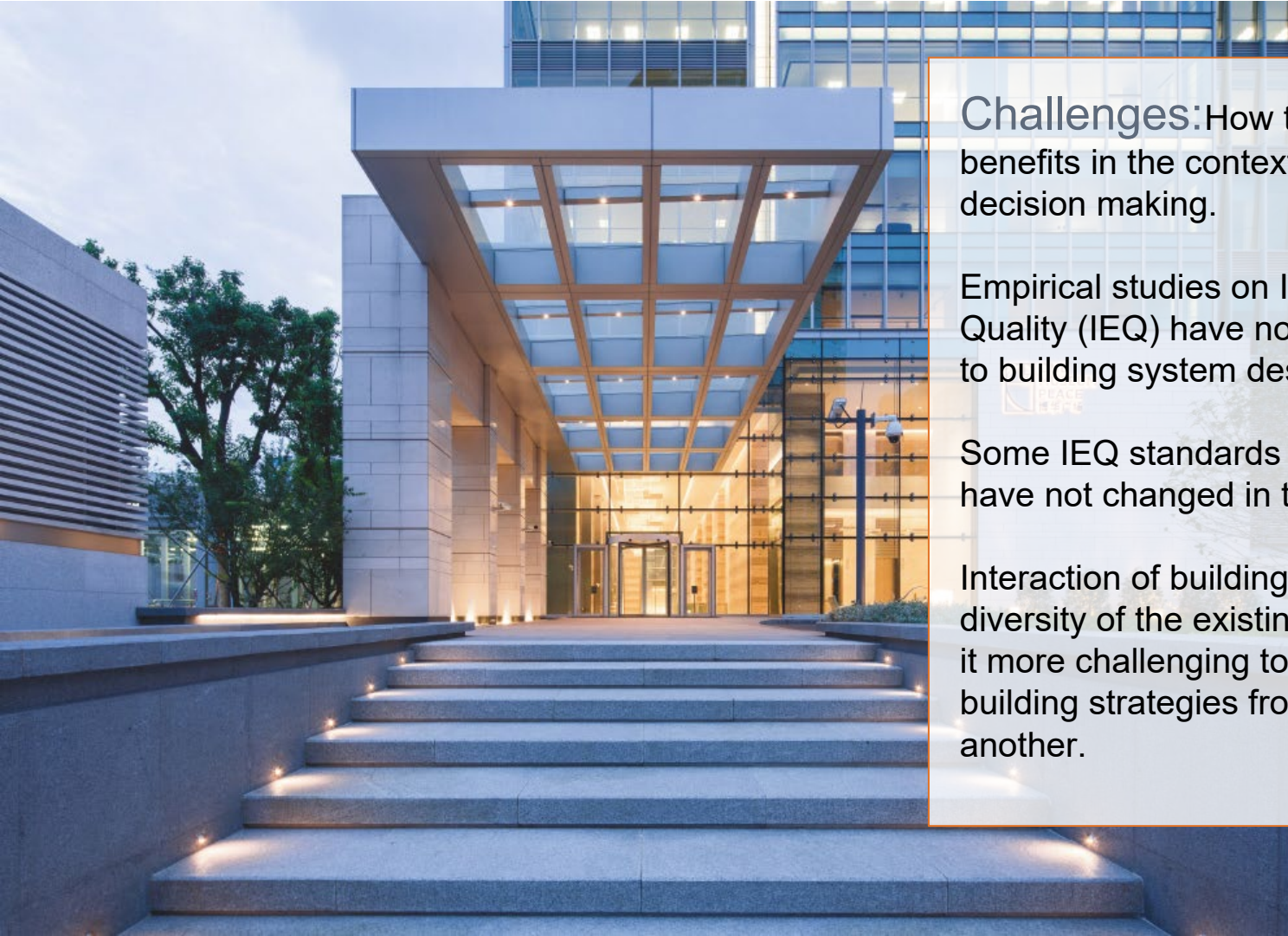
Non-energy benefits, such as health and productivity improvements, can have large economic benefits—which are currently unaccounted for in energy efficiency project valuation methodologies.

Leveraging buildings to achieve broader energy goals (demand reduction, smart buildings, building-grid integration) requires gaining knowledge and developing measurement of human outcomes, which represent the best interest of building owners, business owners, and building occupants.

### 3-30-300

On average, companies spend \$3 in utilities, \$30 in rent, and \$300 in payroll per square foot per year.

# HBI Background



**Challenges:** How to quantify occupant benefits in the context of energy efficiency decision making.

Empirical studies on Indoor Environmental Quality (IEQ) have not been fully translated to building system design and operation.

Some IEQ standards for building design have not changed in the past 100 years.

Interaction of building systems and diversity of the existing installations makes it more challenging to translate healthy building strategies from one building to another.

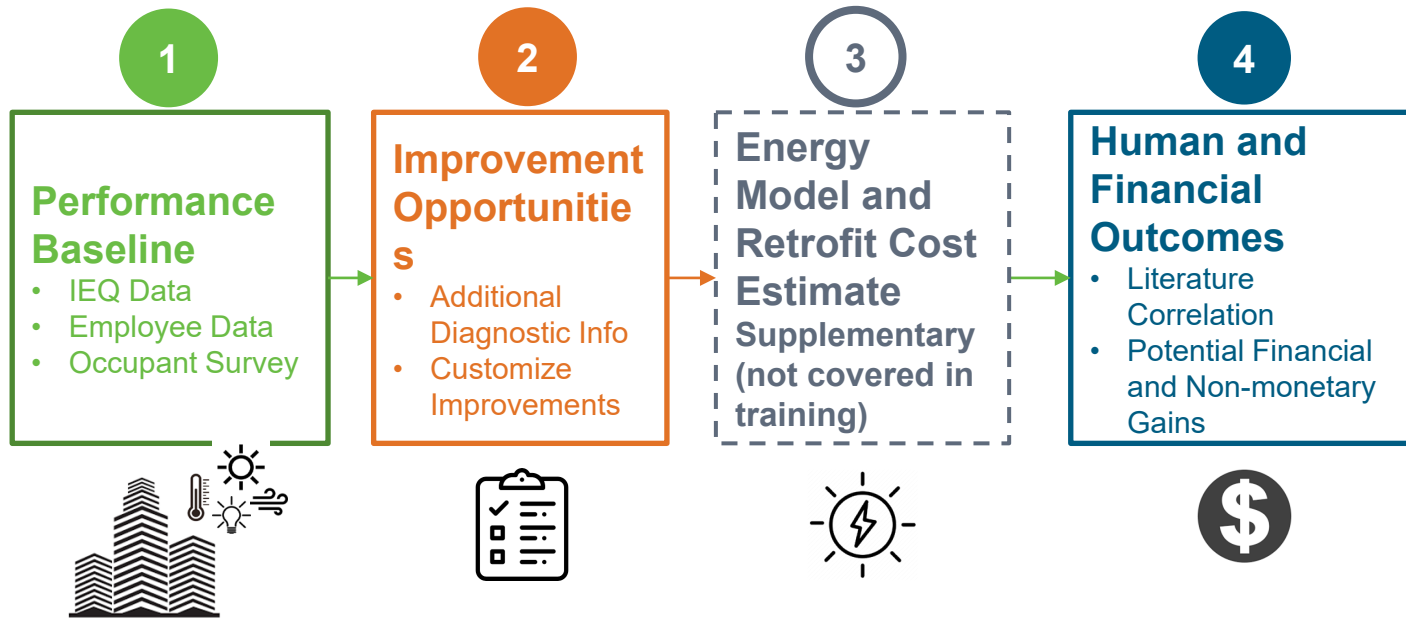
# HBI Background



## HBI Program -in-a-Box

- The purpose of **HBI** is to integrate occupants' health outcomes with energy efficiency measures, quantify potential financial benefits from productivity gains, and help building managers make holistic decisions on building retrofits and operation.
- **Program -in-a-box** is a toolkit that includes a data collection guide, a cost-benefit calculator, and an equipment library to support facility managers to implement HBI.

# HBI Framework Overview





# IEQ Metrics and Data Collection

## Inputs for Step 1

## Inputs for Step 2

Category	Baseline Metrics	Diagnostics Information
Lighting	Horizontal Illuminance Lighting Satisfaction Complaints	Task Lighting
	Circadian Stimulus Daylight Satisfaction Cubicle Height	Window Proximity
	Glare Satisfaction	Blinds, shades, etc. Desks configured perpendicular to windows Architectural shading
Indoor Air Quality	Particulate Matter	Air Filters
		Combustion Equipment
		Positive Building Pressure
		Outdoor Air Intake Location
		Ventilation Rate
	Carbon Dioxide	HVAC testing and balancing
		Air Distribution Effectiveness
		VAV Boxes
	VOC (no baseline metric)	HVAC testing and balancing
Green Cleaning Policy		
Thermal Comfort	Predictive Mean Vote Temperature Satisfaction Seasonal Satisfaction	Personal Thermal Devices
		Enclosure Heat Loss/Gain

## 2 Improvement Recommendations

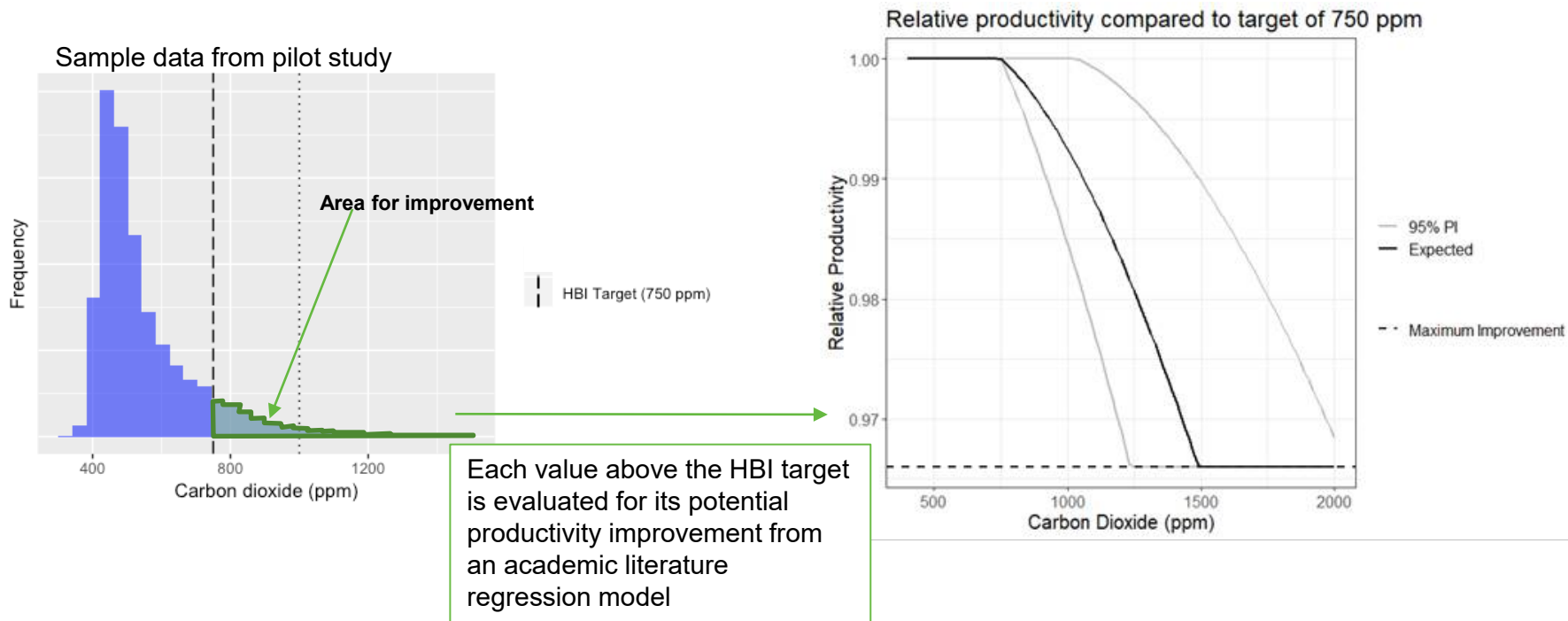
Customized improvements based on inputs.

Example from pilot study:

IEQ Measurement	Recommendations
Thermal Comfort	<ul style="list-style-type: none"><li>• Increase temperature setpoint in spring and summer in the building from 20°C to 24°C (68°F to 75°F). Increase temperature setpoint in conference rooms in summer to 23°C to 25°C (73°F to 77°F).</li><li>• Humidify the outdoor air intake in fall and winter to get at least 30-40% relative humidity indoors.</li><li>• Monitor temperature and humidity to ensure modifications improve PMV as expected.</li></ul>
Indoor Air Quality	<ul style="list-style-type: none"><li>• Increase minimum ventilation rates in the afternoon at all locations, especially Tuesdays through Thursdays.</li><li>• Investigate the operation of the demand control ventilation system in conference rooms on the ground floor.</li><li>• Investigate activities taking place in workrooms that could be causing high particulate matter. If the activities are essential, install a dedicated exhaust system to remove the pollutants.</li></ul>
Lighting	<ul style="list-style-type: none"><li>• In the ground floor, install dimmable, blue LED task lights that can provide 0.3 CS and educate occupants of the benefits of one hour of exposure between 9AM and 1PM.</li></ul>

# 4

## Potential Productivity Improvement



## 4

## Cost-Benefit Analysis

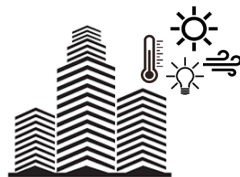
The potential productivity improvement is converted to financial gains based on the cost of employees.

Example from pilot building:

Category	Energy 10-year NPV	Estimated retrofit cost	Productivity 10-year NPV	Overall 10-NPV	Benefit/ cost ratio	Sleep Efficiency Improvement	Sleep Latency Improvement
Indoor Air Quality	\$57k	\$0	\$0	\$57k	N/A	N/A	N/A
Thermal Comfort	-\$7k	\$127k	\$2,133k	\$1,999k	16.7	N/A	N/A
Lighting	-\$1k	\$26k	\$30k	\$3k	1.1	10.4%	21.3%
Combined	\$44k	\$153k	\$2,163k	\$2,045k	14.4	10.4%	21.3%

Default discount rate: 3%

Capital costs paid upfront



# 1. Performance Baseline

# Overview

A

IEQ Sensor Data (CO2, Temp, RH, PM, CS, Illum.)



B

Occupant Survey

How satisfied are you with the following

Very satisfied	Satisfied	Neither satisfied nor dissatisfied	Dissatisfied	Very dissatisfied
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
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<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

C

Aggregated Employee Data

Excel HR Salary Sample Data Set			
ID	Region	Country	City
1	NORTH AMERICA	CANADA	TORONTO ONT
2	NORTH AMERICA	CANADA	TORONTO ONT
3	NORTH AMERICA	CANADA	TORONTO ONT
4	NORTH AMERICA	CANADA	TORONTO ONT
5	NORTH AMERICA	CANADA	TORONTO ONT
6	NORTH AMERICA	CANADA	TORONTO ONT
7	NORTH AMERICA	CANADA	TORONTO ONT
8	NORTH AMERICA	CANADA	TORONTO ONT
9	NORTH AMERICA	CANADA	TORONTO ONT
10	NORTH AMERICA	CANADA	TORONTO ONT
11	NORTH AMERICA	CANADA	TORONTO ONT
12	NORTH AMERICA	CANADA	TORONTO ONT
13	NORTH AMERICA	CANADA	TORONTO ONT
14	NORTH AMERICA	UNITED STATES	LOS ANGELES CA
15	NORTH AMERICA	CANADA	TORONTO ONT
16	NORTH AMERICA	UNITED STATES	LOS ANGELES CA
17	NORTH AMERICA	UNITED STATES	LOS ANGELES CA
18	NORTH AMERICA	UNITED STATES	LOS ANGELES CA
19	NORTH AMERICA	UNITED STATES	NEW YORK NY
20	SOUTH AMERICA	BRAZIL	PROF. ABERIO DC

## A IEQ Sensor Data Overview

**Metrics:** Temperature, Humidity, and Carbon Dioxide



This guide uses Onset HOB0 MX1102 as an example for equipment. This product is not endorsed by PNNL or DOE. The manual for this product can be found [here](#).

- **CO<sub>2</sub>** is a metric of indoor air quality (IAQ). Temperature and humidity are used to calculate **Predictive Mean Vote (PMV)<sup>1</sup>**.
- Data loggers capture interval data (~15 min. increments) for CO<sub>2</sub>, temperature and humidity, because these parameters can vary significantly throughout time.
- Building Automation System (BAS) data can be used in lieu of data loggers, but with caution.
  - Be sure the sensor placement meets the guidance criteria from the following slides.

<sup>1</sup>PMV is a unitless measure of thermal sensation on a scale of -3 (cold) to +3 (hot).

# A

## IEQ Sensor Data Guidance

**Metrics:** Temperature, Humidity, and Carbon Dioxide



Example of a good sensor location: on an occupant's desk but out of their way.

- Duration: one to two typical work weeks per location.
  - Recommended to repeat for each season.
- Sample size: 8 locations per 50k sq.ft.
  - Variety of spaces (floors, wings, HVAC zones, etc.)
  - Only in conference rooms, enclosed offices, and open offices.
- Placement: place the sensors to reflect the occupants' experience.
  - Consider distance to windows and heaters.
  - Should be in general breathing zone (i.e., not on floor, wall, or ceiling).
- See Appendix A for an example on selecting locations and Appendix B for instructions on how to setup the HOBO MX1102.





## IEQ Sensor Data Overview

**Metrics:** Circadian Stimulus,  
and Horizontal Illuminance



This guide uses Asense Lighting Passport as an example for equipment. This product is not endorsed by PNNL or DOE. Source: [Allied Scientific Pro](#).

- Circadian stimulus indicates the ability for light to suppress melatonin and is important for sleep quality.
- Horizontal illuminance is the light hitting a horizontal surface (e.g. desk) and is important for visual performance.
- Spot measurements (one measurement per location) used circadian stimulus and horizontal illuminance.
- Continuous measurements can be used if available, but must only be during workday (filter out weekends and nights).



## IEQ Sensor Data Guidance

**Metrics:** Circadian Stimulus,  
and Horizontal Illuminance



Example of measuring circadian stimulus.

- Sample size: 20 locations per 50k sq.ft.
  - Variety of spaces (floors, wings, lighting fixture types, etc.)
  - Only in conference rooms, enclosed offices, and open offices
  - At window locations, measure once for four days and average. At core locations, only one measurement per location.
- Placement: place the sensors to reflect the occupants' experience.
  - Lighting sensors are sensitive to window proximity and light conditions (e.g. shades, dimmers, time of day, etc.)
  - Do not measure in spaces that occupants make intentionally dark or dim.
- See Appendix A for an example on selecting locations and Appendix C for instructions on how to setup the Asensetek Lighting Passport.



## IEQ Sensor Data Overview and Guidance

**Metrics:** Particulate Matter  
(PM<sub>2.5</sub> and PM<sub>10</sub>)



Aeroqual Series 200 with the particulate matter sensor head attachment is used as equipment example. This product is not endorsed by PNNL or DOE. The user manual for this device can be found [here](#).

- Particulate matter is small airborne particles (diameter less than 2.5  $\mu\text{m}$  or 10  $\mu\text{m}$ ) from smoke, dust or other pollutants that can cause adverse health effects.
- Spot measurements (one measurement per location) used for particulate matter.

### Guidance:

- Sample size: 20 locations per 50k sq.ft.
  - Variety of spaces (floors, wings, HVAC zones, etc.)
  - Only in conference rooms, enclosed offices, and open offices
- See Appendix A for an example on selecting locations and Appendix D for instructions on how to setup the Aeroqual Series 200.

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**B**

## Occupant Survey

- The survey collects information about occupant satisfaction that will be used to help identify specific improvement recommendations.
- This program recommends [SurveyMonkey](#) as a survey platform, which is free for a basic account.
  - You may use any survey response platform, but you may need to process the results to conform with the Excel tool's inputs.
- The survey can be sent via a building email list with a one- to two-week timeframe for responses.
- See Appendix E for instructions on how to set up, deploy, and collect the results of a survey.

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## C Employee Info

Metric	Notes
<b>Number of Employees</b>	Number of regular employees in building. If the number of employees is not available, the financial results can still be presented in financial gains per employee.
<b>Average Cost of Employee</b> (Salary + Benefits)	Can use the average salary x 1.3 for the approximate cost of the employees. See following slide for how to find the default value.

## C Employee Info

GS General Schedule Pay Calculator

1 What state do you work in?

2 What county do you work in?

3 What is your GS Paygrade and Step?

Washington

Benton County

GS-1

STEP 1

2020 GS Pay Table

Calculate My GS Pay

<https://www.federalpay.org/gs/calculator>

- The General Schedule Pay Calculator can be used if the actual employee salary is not available.
- On the website in the link, enter the state and county the building is located in, and then average GS level and step for the building.
- Then press calculate to get the average adjusted salary for your location.
- If the average GS level is not known, you can give an estimate. For reference, the average GS-level of all federal employees is 10.38 (Level 10, Step 4) and 12.53 for the DC metro area.<sup>1</sup>

<sup>1</sup> <https://www.opm.gov/policy-data-oversight/data-analysis-documentation/federal-employment-reports/reports-publications/profile-of-federal-civilian-non-postal-employees/>

2

Improvement  
Opportunities



## 2. Improvement Opportunities

## Diagnostic Metrics

- The diagnostic metrics that are required to complete will depend on the results of the baseline metrics.
- If the baseline metrics show that there is little room for improvement, then no diagnostic info is needed in that area.
- If there is room for improvement, the diagnostic info helps identify what could be done to improve.

Category	Baseline Metrics	Diagnostics Information
Lighting	Horizontal Illuminance Lighting Satisfaction Complaints	Task Lighting
	Circadian Stimulus Daylight Satisfaction Cubicle Height	Window Proximity
	Glare Satisfaction	Blinds, shades, etc. Desks configured perpendicular to windows Architectural shading
Indoor Air Quality	Particulate Matter	Air Filters
		Combustion Equipment
		Positive Building Pressure
		Outdoor Air Intake Location
Carbon Dioxide	Carbon Dioxide	Ventilation Rate
		HVAC testing and balancing
		Air Distribution Effectiveness
VOC (no baseline metric)	VOC (no baseline metric)	VAV Boxes
		HVAC testing and balancing
		Green Cleaning Policy
Thermal Comfort	Predictive Mean Vote Temperature Satisfaction Seasonal Satisfaction	Low-emitting Materials
		Personal Thermal Devices Enclosure Heat Loss/Gain



# Diagnostic Metrics

- After completing all other inputs, the “Required” column in “Diagnostics” tab in the Excel tool will tell you which categories to complete.

Required	Metric	Diagnostic Info	
YES	VOC	There is a policy in place that requires the use of Green Seal, UL Ecolabel, or EPA Safer Choice cleaning products?	
YES	VOC	100% of the furniture and furnishings purchased in the last two years were determined compliant in accordance to a third-party certification for low-VOC emissions.	
YES	VOC	100% of the paint, sealant, and adhesive materials installed in the last two years were determined compliant in accordance to a third-party certification for low-VOC emissions.	
YES	VOC	100% of the flooring materials (carpets, etc.) installed in the last two years were determined compliant in accordance to a third-party certification for low-VOC emissions.	TWS 2.1-4; LEED v4 EQ Low-Emitting Mat
YES	VOC	If building was constructed in the previous two years, 100% of the insulation and wood materials used in the construction were determined compliant in accordance to a third-party certification for low-VOC emissions. Answer YES if not constructed in the previous two years.	TWS 2.1-4; LEED v4 EQ Low-Emitting Mat
NO	VOC	What is the ventilation rate (outdoor air supply) to the building during occupied hours?	TWS 2.1-12; WELL A03 p1/ A06 p1
YES	Glare	Windows (north-facing windows not necessary) have architectural features (e.g., exterior shading, interior light shelves, electrochromic glass) that minimize direct sun in spaces.	TWS 2.3-8; WELL L04 p1
YES	Glare	Most (~80%) of desks or desktop monitors that receive light from exterior windows are intentionally configured to be perpendicular to the windows.	TWS 2.3-9
NO	Glare	Window treatments (e.g., exterior shading, interior light shelves, electrochromic glass) are automated via light sensor or are user-adjustable to allow control over the amount of daylight.	TWS 2.3-7; WELL L04 p1
NO	PM	There are no outdoor air intakes (for example, an air handler unit) close to a direct exhaust vent, idling vehicles or other source of outdoor air contamination.	TWS 2.1-11
		Carbon or combination carbon/particle filters with a mechanical efficiency rating	

# Diagnostic Metrics

Required	Metric	Diagnostic Info	Response	Source
YES	VOC	There is a policy in place that requires the use of Green Seal, UL Ecolabel, or EPA Safer Choice cleaning products?		TVS 2.1-3
YES	VOC	100% of the furniture and furnishings purchased in the last two years were determined compliant in accordance to a third-party certification for low-VOC emissions.		TVS 2.1-4; LEED v4 EQ Low-Emitting Mat
YES	VOC	100% of the paint, sealant, and adhesive materials installed in the last two years were determined compliant in accordance to a third-party certification for low-VOC emissions.		TVS 2.1-4; LEED v4 EQ Low-Emitting Mat
YES	VOC	100% of the flooring materials (carpets, etc.) installed in the last two years were determined compliant in accordance to a third-party certification for low-VOC emissions.		TVS 2.1-4; LEED v4 EQ Low-Emitting Mat
		If building was constructed in the previous two years, 100% of the insulation and wood materials used in the construction were determined compliant in accordance to a third-party certification for low-VOC emissions. Answer YES if not		TVS 2.1-4; LEED v4 EQ Low-Emitting Mat
		occupied		TVS 2.1-12; WELL A03 p1/ A06 p1
		ures (e.g., hize direct		TVS 2.3-8; WELL L04 p1
		or ws. ochromic ontrol over		TVS 2.3-9
NO	Glare	the amount of daylight.		TVS 2.3-7; WELL L04 p1
NO	PM	There are no outdoor air intakes (for example, an air handler unit) close to a direct exhaust vent, idling vehicles or other source of outdoor air contamination.  Carbon or combination carbon/particle filters with a mechanical efficiency rating		TVS 2.1-11

- For the rows that have “YES” in the “Required” column, fill in your response in the “Response” column.

# Diagnostic Metrics – Volatile Organic Compounds (VOCs)

- Five of the VOC questions are required for all buildings.
  - These are used as screening questions because measuring total VOC is difficult and expensive to do accurately.
  - The questions about cleaning products and materials that are common sources of VOCs. If they are not certified as low-emitting then there is a potential for high VOC levels within the space.
- Materials more than two years in age are not of concern as the material has likely stopped emitting and the VOCs are most likely flushed out.

Question	Diagnostic Info
VOC	There is a policy in place that requires the use of Green Seal, UL Ecolabel, or EPA Safer Choice cleaning products.
VOC	100% of the furniture and furnishings purchased in the last two years were determined compliant in accordance to a third-party certification for low-VOC emissions.
VOC	100% of the paint, sealant, and adhesive materials installed in the last two years were determined compliant in accordance to a third-party certification for low-VOC emissions.
VOC	100% of the flooring materials (carpets, etc.) installed in the last two years were determined compliant in accordance to a third-party certification for low-VOC emissions.
VOC	If building was constructed in the previous two years, 100% of the insulation and wood materials used in the construction were determined compliant in accordance to a third-party certification for low-VOC emissions. Answer YES if not constructed in the previous two years.
VOC	What is the ventilation rate (outdoor air supply) to the building during occupied hours?

# Diagnostic Metrics – Volatile Organic Compounds (VOCs)

- The last VOC question is about the ventilation rate (outdoor air supply rate) for the building.
- Ventilation rate is usually designed based on the typical occupancy of building.
- Some buildings are designed to have a constant outdoor air supply in cubic feet per minute per person (CFM/person).
- Others may have varying ventilation rate based on measured CO<sub>2</sub> levels to match occupancy.
- Answer from the drop-down that best describes your building.

Ventilation Rate Responses
Less than ASHRAE 62.1/Don't know
Designed to ASHRAE 62.1 (17 CFM/person* or 1,100 ppm CO <sub>2</sub> )
Designed to 30% above ASHRAE 62.1
Designed to 60% above ASHRAE 62.1 or higher

\* From ASHRAE 62.1 Table 6.2.2.1, which assumes an occupant density of 5 people/1,000 sq.ft.

# Diagnostic Metrics – Solar Glare

- The required glare questions will depend on the results of the occupant survey.
- The questions ask about ways the building controls for glare to identify what the possible options are for reducing glare if the occupants are dissatisfied.
- Answer YES or NO/DON'T KNOW from the drop down menu

Question	Diagnostic Info
Glare	Windows (north-facing windows not necessary) have architectural features (e.g., exterior shading, interior light shelves, electrochromic glass) that minimize direct sun in spaces.
Glare	Most (~80%) of desks or desktop monitors that receive light from exterior windows are intentionally configured to be perpendicular to the windows.
Glare	Window treatments (e.g., exterior shading, interior light shelves, electrochromic glass) are automated via light sensor or are user-adjustable to allow control over the amount of daylight.

# Diagnostic Metrics – Particulate Matter

- The required particulate matter (PM) questions will depend on the results of the PM measurements.
- The questions ask about potential sources of PM contamination.
- Answer YES or NO/DON'T KNOW from the drop down menu

Question	Diagnostic Info
PM	There are no outdoor air intakes (for example, an air handler unit) close to a direct exhaust vent, idling vehicles or other source of outdoor air contamination.
PM	Carbon or combination carbon/particle filters with a mechanical efficiency rating value (MERV) of 13 or higher are installed and regularly replaced or maintained.
PM	There is no combustion-based heating equipment in the building.
PM	HVAC system has undergone testing and balancing at least once every 5 years.
PM	Building can maintain positive building pressure. For example, air flows outwards when opening doors.

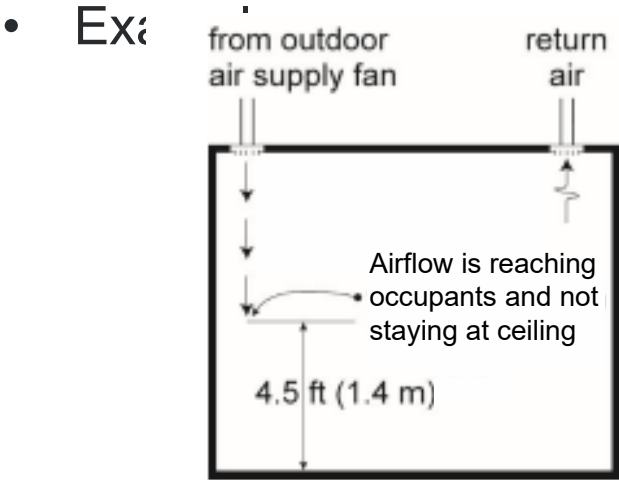
# Diagnostic Metrics – Carbon Dioxide

- The required carbon dioxide (CO<sub>2</sub>) questions will depend on the results of the CO<sub>2</sub> measurements and the air quality complaints from the occupant survey.
- The questions ask about HVAC maintenance and design.
- Answer YES or NO/DON'T KNOW from the drop down menu for if the HVAC undergoes testing and balancing every 5 years.

Question	Diagnostic Info
CO2	HVAC system has undergone testing and balancing at least once every 5 years.
CO2	What is the air distribution effectiveness (select from options)?
CO2	What type of ventilation system is used?
CO2	What is the ventilation rate (outdoor air supply) to the building during occupied hours?

# Diagnostic Metrics – Carbon Dioxide

- Air distribution effectiveness asks about the set up of supply and return air in spaces to approximate and quantify how well the air circulates through a space



During heating season (winter), supply air is warmer than space temperature and will rise to the ceiling. The supply air velocity needs to be strong enough so that air reaches occupants despite temperature differential

Air Distribution Effectiveness Responses
Ceiling supply and floor return
Ceiling supply and ceiling return, and during heating season airflow is noticeable at chest level below vents.
Ceiling supply and ceiling return, and during heating season airflow is NOT noticeable at chest level below vents.
Floor supply and ceiling return on opposite sides of room, and during cooling season airflow is noticeable at chest level above vents
Floor supply and ceiling return on opposite sides of room, and during cooling season airflow is NOT noticeable at chest level above vents
Floor supply near ceiling return
Floor supply and floor return on opposite sides of room
Floor supply near floor return



# Diagnostic Metrics – Carbon Dioxide

- The third question asks about whether the HVAC system uses variable air volume (VAV) boxes with reheat, VAV without reheat, or constant air volume (CAV).
- The final question is the ventilation rate in the building. Ventilation rate is usually designed based on typical occupancy of building.
  - Some buildings are designed to have a constant outdoor air supply in cubic feet per minute per person (CFM/person). Others may have varying ventilation rate based on measured CO<sub>2</sub> levels to match occupancy.

Ventilation System Responses
VAV boxes with reheat
VAV boxes without reheat
CAV

Ventilation Rate Responses
Less than ASHRAE 62.1/Don't know
Designed to ASHRAE 62.1 (17 CFM/person* or 1,100 ppm CO <sub>2</sub> )
Designed to 30% above ASHRAE 62.1
Designed to 60% above ASHRAE 62.1 or higher

\* From ASHRAE 62.1 Table 6.2.2.1, which assumes an occupant density of 5 people/1,000 sq.ft.

# Diagnostic Metrics – Predictive Mean Vote

- The required predictive mean vote (PMV) questions will depend on the results of the PMV measurements and the results of the occupant survey.
- The two questions ask about if thermal comfort devices are made available to occupants and if there are noticeable drafts or temperature differential in the winter.
- If it's not currently winter, then use best judgment based on memory or answer "NO/DON'T KNOW" if you are uncertain.

Question	Diagnostic Info
PMV	Occupants have access to personal thermal devices (e.g., personalized fans, heated/cooled chairs, electric space heaters).
PMV	The window and wall temperature is similar to the indoor temperature to the touch and there are minimal drafts evident in winter.

## Final results of Improvement Recommendations

- The “Improve. Results” tab shows the recommended improvements for the building based in the input data.
- Note that after entering inputs you must close and re-open the Excel document to refresh the Pivot tables and get recommendations.

Improvement Recommendations				Location(s)	Health Impact	EE Impact	Cost	Recommendations
Category	Recommendation 1	Details						
Carbon Dioxide	<b>Ventilation schedule</b>	Install modulation damper at outdoor air intake (if not already there) and set up ventilation schedule according to problematic times or use CO2 sensor to control damper position (DCV).	AHU 2	+	++	+		
Particulate Matter								
Volatile Organic Compounds								
Predictive Mean Vote (Thermal Comfort)	<b>Check thermostat location</b>	First priority is to make sure that HVAC system is receiving the right info. Check that building temperature sensors/thermostats are in locations that reflects occupants' experience and if not change their location.	Floor 1, East, Floor 1, West	++	+	+		<b>Adjust temperature setpoints</b>
Horizontal Illuminance (Electric Lighting)								
Circadian Stimulus (Daylighting)	<b>Reduce partition height</b>	Reduce partition height to below eye level or add translucent glass at eye level and above. This will increase horizontal illuminance as well.	Floor 1 North	+	+	+		<b>Translucent/transparent wall sections</b>
Solar Glare								

## Final results of Improvement Recommendations

- Each row refers to an IEQ metric.
- The recommendation(s), if any, will be listed horizontally on that row, each followed by additional information about the recommendation.
- The “Location” column shows the zones that recommendations should be applied to.
- The “Health Impact”, “EE Impact”, and “Cost” give a very general sense of the relative impact that upgrade may have.
- No value means no impact, very little impact, or varies; one ‘+’ means some impact; and two ‘++’ means large impact.

Improvement Recommendations								
Category	Recommendation 1	Details	Location(s)	Health Impact	EE Impact	Cost	Recommendation 2	
Carbon Dioxide	Ventilation schedule	Install modulation damper at outdoor air intake (if not already there) and set up ventilation schedule according to problematic times or use CO2 sensor to control damper position (DCV).	AHU 2	+	++	+		

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## Diagnostic Metrics – Horizontal Illuminance

- The horizontal illuminance question will depend on the results of the illuminance measurements.
- Answer YES or NO/DON'T KNOW from the drop down menu

Question	Diagnostic Info
Hor. Illumn.	Occupants have task lighting at their workstations.

4

Human and  
Financial  
Outcomes



# 3. Human and Financial Outcomes

## Final results of Financial Calculations

- The “Fin. Results” tab of the Excel tool displays a table with the monetized health gains, the energy savings (if entered as input), the costs (if entered as input), and the total expected net present value and benefit/cost ratio.

Potential Financial and Non-monetary Gains							
	Health	Energy	Costs	Total Monetary		Non-Monetary	
	Expected NPV	NPV	Capital + Certification Cost	Total Expected NPV	Benefit / Cost Ratio	Sleep Latency	Sleep Efficiency
<b>IAQ</b>	\$9,295	\$4,265	\$0	\$13,561	N/A	N/A	N/A
<b>Thermal Comfort</b>	\$4,412,891	\$2,559	-\$100,000	\$4,315,450	44.2	N/A	N/A
<b>Lighting</b>	\$825,938	\$1,706	-\$70,000	\$757,644	11.8	25.35%	3.18%
<b>Combined</b>	\$5,238,829 *	\$5,118	-\$170,000	\$5,073,094	30.8	25.35%	3.18%

\* This is the expected outcome, but the 95% prediction interval ranges between \$592,674 and \$6,934,461

...	Cont. Monitor Data	Spot Data	Survey Data	Diagnostics	<b>Fin. Results</b>	Improve. Results	Cont. Calcs	Spot Calcs	Z
-----	--------------------	-----------	-------------	-------------	---------------------	------------------	-------------	------------	---

## Final results of Financial Calculations

- Included in the health gains is increased productivity and reduced absenteeism due to influenza virus transmission (in thermal comfort).
- A regression was created between vapor pressure (a function of temperature and humidity) and transmission reduction. Transmission reduction is monetized using a national average time missed per year due to flu sickness and the cost of employee.

Potential Financial and Non-monetary Gains							
	Health	Energy	Costs	Total Monetary		Non-Monetary	
	Expected NPV	NPV	Capital + Certification Cost	Total Expected NPV	Benefit / Cost Ratio	Sleep Latency	Sleep Efficiency
<b>IAQ</b>	\$9,295	\$4,265	\$0	\$13,561	N/A	N/A	N/A
<b>Thermal Comfort</b>	\$4,412,891	\$2,559	-\$100,000	\$4,315,450	44.2	N/A	N/A
<b>Lighting</b>	\$825,938	\$1,706	-\$70,000	\$757,644	11.8	25.35%	3.18%
<b>Combined</b>	\$5,238,829 *	\$5,118	-\$170,000	\$5,073,094	30.8	25.35%	3.18%

\* This is the expected outcome, but the 95% prediction interval ranges between \$592,674 and \$6,934,461



## Final results of Financial Calculations

- Under Non-Monetary benefits is percent reduction in sleep latency (time taken to fall asleep) and increase in sleep efficiency (percent of time in bed asleep).
- Regressions were created between circadian stimulus and sleep latency and sleep efficiency.
- The sleep latency target (at 0.3 CS) is 20.9 minutes. The maximum improvement is 53% (from 44.6 minutes at 0.0 CS to the target).
- The sleep efficiency target (at 0.3 CS) is 81.5%. The maximum improvement is 5.8% (from 75.7% at 0 CS to target).

Potential Financial and Non-monetary Gains							
	Health	Energy	Costs	Total Monetary		Non-Monetary	
	Expected NPV	NPV	Capital + Certification Cost	Total Expected NPV	Benefit / Cost Ratio	Sleep Latency	Sleep Efficiency
IAQ	\$9,295	\$4,265	\$0	\$13,561	N/A	N/A	N/A
Thermal Comfort	\$4,412,891	\$2,559	-\$100,000	\$4,315,450	44.2	N/A	N/A
Lighting	\$825,938	\$1,706	-\$70,000	\$757,644	11.8	25.35%	3.18%
Combined	\$5,238,829 *	\$5,118	-\$170,000	\$5,073,094	30.8	25.35%	3.18%

\* This is the expected outcome, but the 95% prediction interval ranges between \$592,674 and \$6,934,461

# Appendix A

## Selecting measurement locations

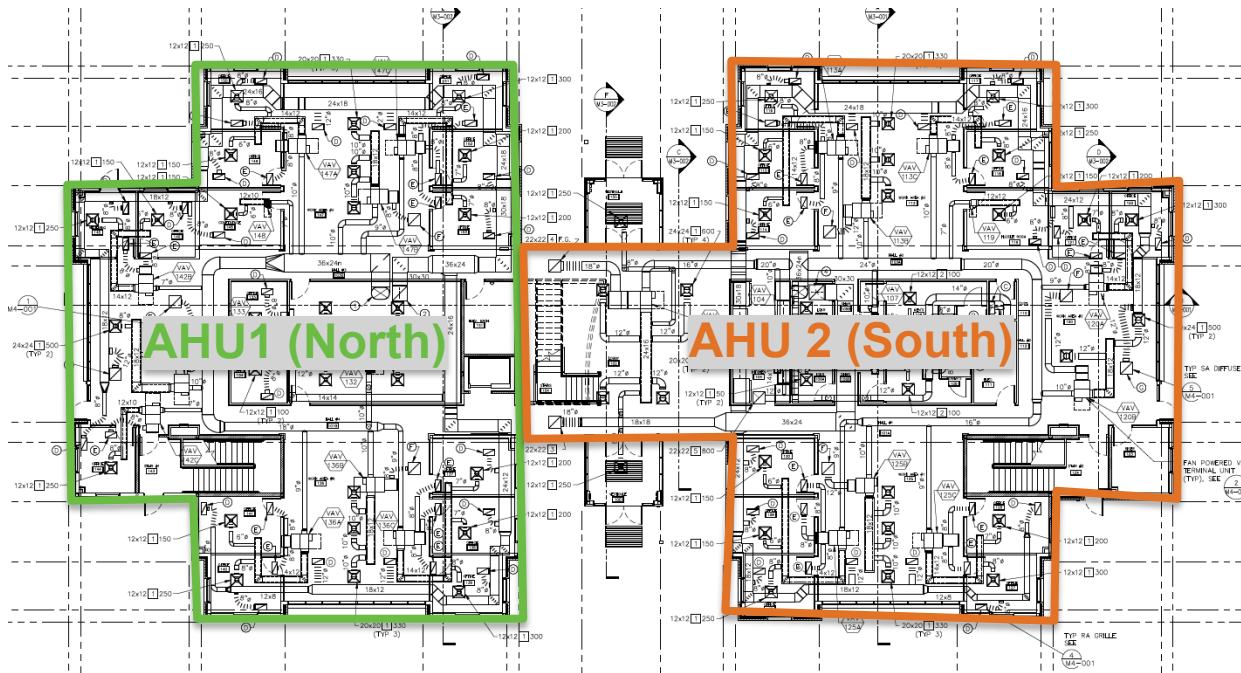
---

## Appendix A

- Identifying zones within the building is useful for identify granular recommendations.
- Instead of “increase the temperature in the entire building”, a recommendation could now be “increase the temperature on the south side of wing 1” (for example), which is perhaps the only zone where the temperature is too low.
- Using example floor plans on the following slides, we will first identify the AHU/RTU zones and then more granular zones.

## Appendix A

- Identify the boundaries of each central ventilation/HVAC unit. Most commercial buildings will have multiple air handler units (AHU) or rooftop units (RTU) that serve large portions of the building.
- If your building does not have centralized mechanical ventilation this may not apply.



- Using the mechanical plans from an example building, we identify that there are two AHUs and their boundaries are drawn on the map.

---

## Appendix A

- This building has two floors, with the AHU zones traveling vertically through each floor. Each of the CO<sub>2</sub>/temperature/humidity data loggers will be associated with one of the two AHUs for the air quality recommendations.
- Each CO<sub>2</sub>/temperature/humidity data loggers will also be assigned a more granular zone and the lighting meter and particulate matter meter will be assigned only a granular zone. See the following slides for an example on selecting granular zones.
- In general, logical units to divide the building for granular zones are floor and wing. This building has two floors and a north wing and a south wing, giving us four easy zones.

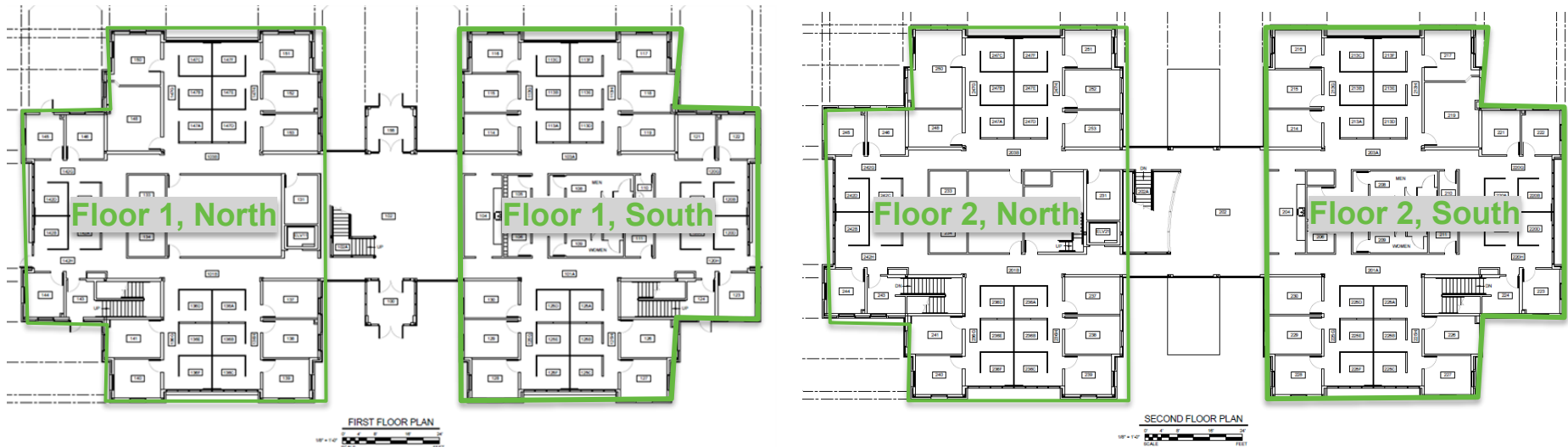
---

## Appendix A

- Beyond that, more zones will give the recommendations more granularity but also will require more measurement burden.
- We want 8 data logger locations per 50,000 sq.ft. and 20 spot measurement locations per 50,000 sq.ft. This building comprises approximately 30,000 sq.ft. of floor area, so we will round up to 8 and 20 locations, respectively.
- We want between two and three locations per zone for the data loggers and about five spot locations per zone for the spot measurements. That comes out to four zones for all devices.
- It is most convenient to use the same zones for all the equipment, but if there are reasons to use different zones that is acceptable.

## Appendix A

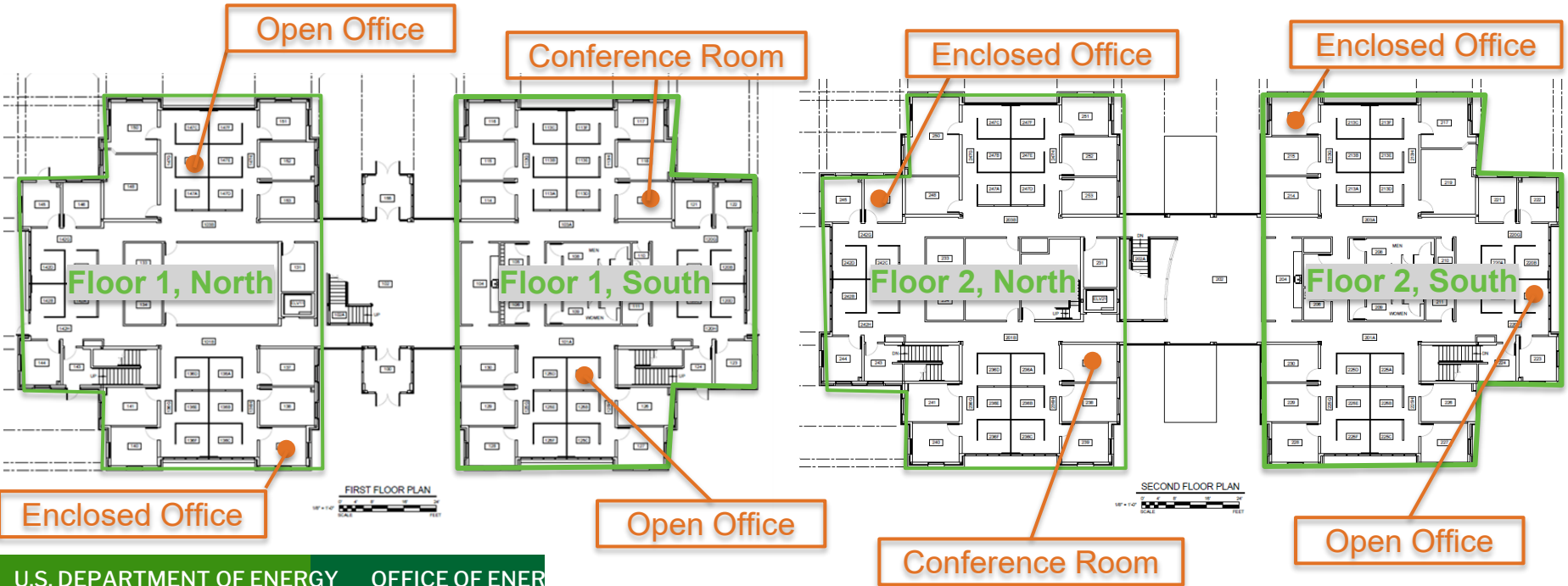
- The logical choice for zones is Floor 1, North; Floor 1, South; Floor 2, North; and Floor 2, South. If we want more zones, we could split each into a perimeter zone and a core zone or east and west zone. Thermal comfort and light can vary between perimeter and core and orientation.



- The center section on both floors is an atrium/lobby and therefore won't be included in the measurements anyway.

# Appendix A

- For the data loggers, we will place two in each zone and look for an representation of Open Office, Enclosed Office, and Conference Rooms, as well as general geographic distribution. Below is an example of what a selection could look like.

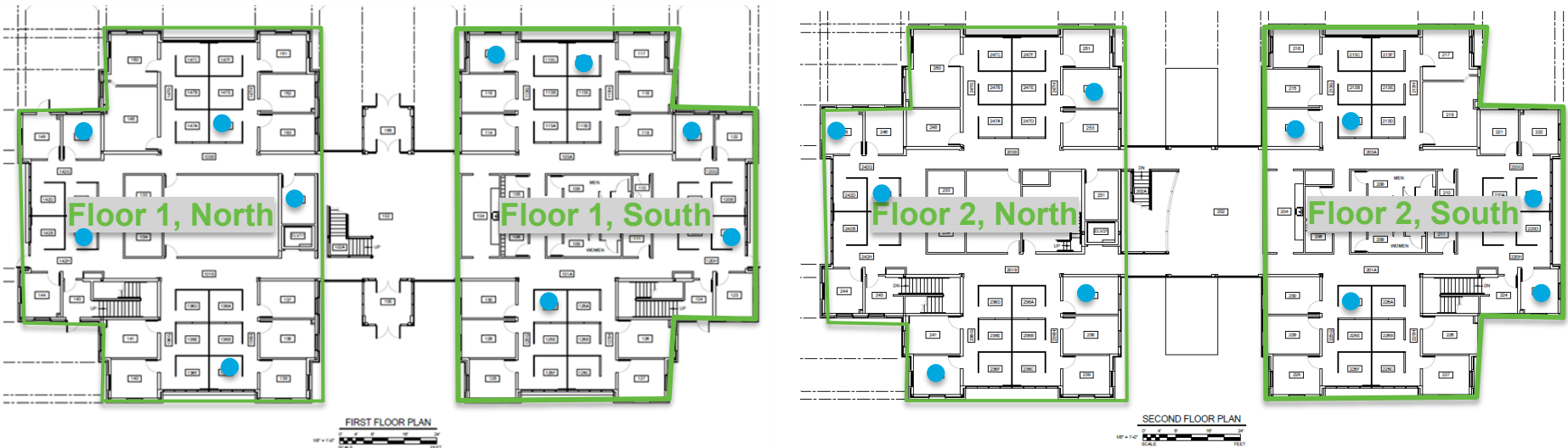




## Appendix A

- For the spot measurements, we will take five in each zone and look for an representation of Open Office, Enclosed Office, and Conference Rooms, as well as general geographic distribution. Below is an example of what a selection could look like.

● Blue dots represent the 20 locations for taking spot measurements



# Appendix B

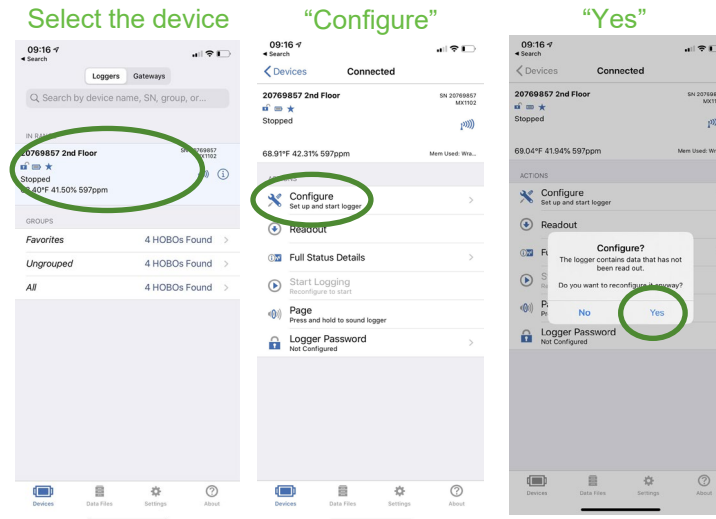
## Onset HOBO MX1102 Set Up

# Appendix B

**Step 1.** Download the “HOBOMobile” app onto to your Android or iOS device.

**Step 2.** Ensure the HOBO devices are powered on, Bluetooth is enabled on your device, and the sensors within range will be listed on the HOBOMobile app.

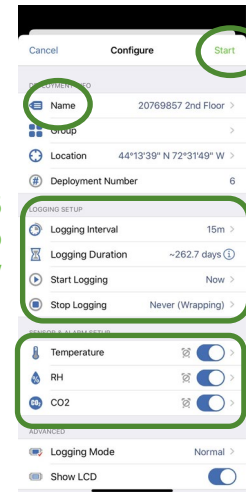
**Step 3.** Follow the screenshots to start the logger. Repeat for each device.



Change name to something identifiable

Set logging interval to 15 minutes and start logging to now

Make sure Temperature, RH, and CO2 are checked and under CO2 enter your altitude



Press “Start” when done to begin logging

## Appendix B

**Step 4.** Calibrate sensors by taking them outdoors away from sources of exhaust or pollution. Let sit for five minutes to adjust to the outdoor air. Hold the “CALIBRATE” button until the device makes a sound and then wait ~10 minutes until the “CALIBRATE” word stops flashing on the screen. The CO2 reading should be in the range of 375 ppm – 450 ppm. If it is not, repeat the calibrate process or try changing locations.



## Appendix B

**Step 5.** Place sensor at its desired locations.

**Step 6.** Open the HOBOMobile app, and select the sensor just placed, click on “Configure” again and press “Start” in the top right to begin logging. If you do not do this the data collected during calibration and transportation will be included in the results.

**Step 7.** Record the location of each sensor with its ID code, room name, space type\*, zone, and associated AHU. See screenshot on where to find the ID on the device. You will need this for data processing.



\*Acceptable Space Types are:

- Open Office
- Enclosed Office
- Conference Room

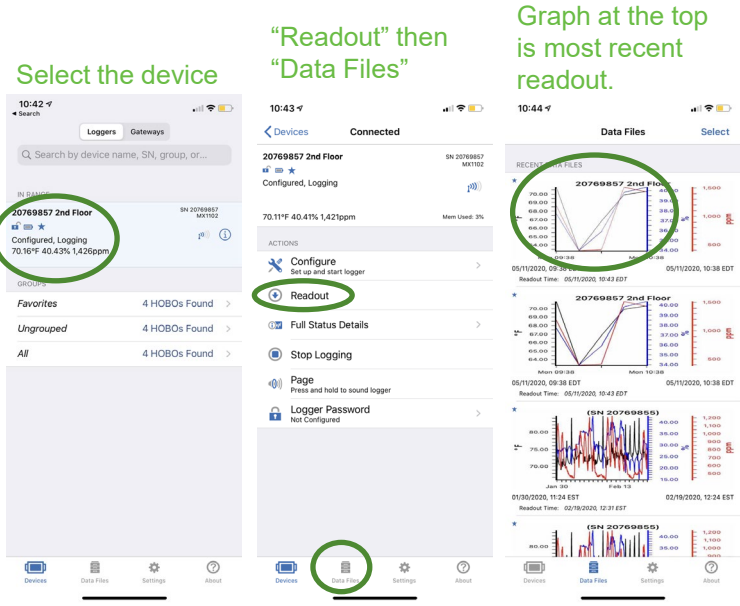
# Appendix B

**Step 8.** Leave sensors to collect data for at least 7 days, checking occasionally that they are working properly and have not been tampered with.

**Step 9.** Every 7 days the sensors must be re-calibrated following the same steps as Step 4.

**Step 10.** After the sampling period is finished, download the data for each sensor following the screenshots.

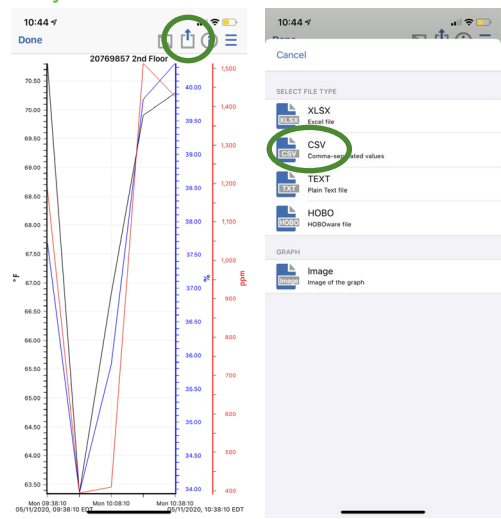
**Step 11.** Place the sensors in the next locations and repeat the process until sample size is met.



"Readout" then "Data Files"

Graph at the top is most recent readout.

Click the export symbol



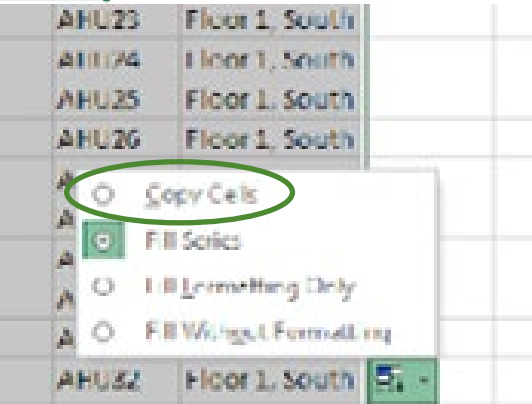
Click CSV or XLSX and follow your phones instructions to email to yourself.

## Appendix B

**Step 12.** Open CSV file and add columns “Space Type”, “Room”, “AHU/RTU”, and “Zone”. See Appendix A for more info on “AHU/RTU” and “Zone”. *Note you must enter something for “AHU/RTU” and “Zone”, even if it is just “Whole Building”.* The sensor ID is in row one if you forget which sensor the spreadsheet belongs to. Fill in the information for the first row.

**Step 13.** Highlight and double click bottom right corner to copy to bottom of spreadsheet. Be sure to select “Copy Cells” and not “Fill Series”.

	A	B	C	D	E	F	G	H	I	J	
1	Plot Title: 20762701										
2	#	Date Time, GMT -0600	Temp, °F	RH, %	CO2, ppm	DewPt, °F	Space Type	Room	AHU/RTU	Zone	
3	1	2020-03-04 10:23:40	74.60	45.36	45.36	543	52.11	Open Office	103A	AHU1	Floor 1, South
4	2	2020-03-04 10:38:40	74.68	45.21		552	52.10				
5	3	2020-03-04 10:53:40	74.81	44.87		584	52.01				
6	4	2020-03-04 11:08:40	74.90	44.75		552	52.01				
7	5	2020-03-04 11:23:40	74.99	44.85		566	52.15				
8	6	2020-03-04 11:38:40	74.94	44.53		548	51.92				
9	7	2020-03-04 11:53:40	74.86	44.38		515	51.75				
10	8	2020-03-04 12:08:40	74.68	44.24		504	51.51				
11	9	2020-03-04 12:23:40	74.55	44.17		536	51.34				
12	10	2020-03-04 12:38:40	74.68	44.38		569	51.59				
13	11	2020-03-04 12:53:40	74.77	44.51		575	51.75				
14	12	2020-03-04 13:08:40	74.86	44.56		559	51.86				
15	13	2020-03-04 13:23:40	74.94	44.17		552	51.70				
16	14	2020-03-04 13:38:40	74.94	43.97		531	51.58				
17	15	2020-03-04 13:53:40	74.94	43.82		568	51.48				
18	16	2020-03-04 14:08:40	75.07	43.77		562	51.57				
19	17	2020-03-04 14:23:40	75.20	43.55		587	51.55				



## Appendix B

**Step 14.** Delete or move “DewPt, F” and column A as it is not needed for calculator. Copy and paste values into “Cont. Monitor Data” tab in Excel tool. Warning messages may appear in column K to make sure your data is in a typical range.

**Step 15.** Repeat Step 12 for each sensor output and then paste at below the data from the previous sensor in the Excel tool.



Paste values

A	B	C	D	E	F	G	H	I	J
Timestamp	Temperature (F)	Humidity (%)	Carbon Dioxide (ppm)	Space Type	Room	AHU/RTU	Zone		
3/4/2020 10:23	74.59667969	45.36132813		543 Open Office	103A	AHU1	Floor 1, South		Warning Messages
3/4/2020 10:38	74.68328094	45.21484375		552 Open Office	103A	AHU1	Floor 1, South	1	
3/4/2020 10:53	74.81321716	44.87304688		584 Open Office	103A	AHU1	Floor 1, South	2	
3/4/2020 11:08	74.8998642	44.75097656		552 Open Office	103A	AHU1	Floor 1, South	3	
3/4/2020 11:23	74.98652649	44.84863281		566 Open Office	103A	AHU1	Floor 1, South	4	
3/4/2020 11:38	74.94319153	44.53125		548 Open Office	103A	AHU1	Floor 1, South	5	
3/4/2020 11:53	74.85653687	44.38476563		515 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 12:08	74.68328094	44.23828125		504 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 12:23	74.55338287	44.16503906		536 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 12:38	74.68328094	44.38476563		569 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 12:53	74.76989746	44.50683594		575 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 13:08	74.85653687	44.55566406		559 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 13:23	74.94319153	44.16503906		552 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 13:38	74.94319153	43.96972656		531 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 13:53	74.94319153	43.82324219		568 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 14:08	75.0732193	43.77441406		562 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 14:23	75.20327759	43.5546875		587 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 14:38	75.0732193	42.96875		503 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 14:53	75.37677002	43.60351563		620 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 15:08	75.29001617	42.99316406		559 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 15:23	75.24664307	42.7734375		559 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 15:38	75.24664307	42.65136719		534 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 15:53	75.24664307	42.52929688		572 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 16:08	75.20327759	42.33398438		524 Open Office	103A	AHU1	Floor 1, South		
3/4/2020 16:23	74.98652649	42.3828125		507 Open Office	103A	AHU1	Floor 1, South		
43894.69352	74.85653687	42.48046875		512 Open Office	103A	AHU1	Floor 1, South		
43894.70394	74.68328094	42.62695313		519 Open Office	103A	AHU1	Floor 1, South		
43894.71435	74.51009369	42.82226563		504 Open Office	103A	AHU1	Floor 1, South		



# Appendix C

## Asensetek Lighting Passport Set Up

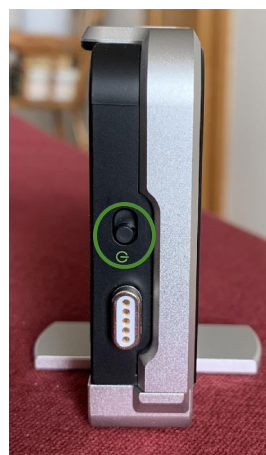
## Appendix C

**Step 1.** Download Spectrum Genius Mobile Plus (SGM+) app (only iPhone compatible currently). The SGM app can be used with Android but does not have CS capability, only illuminance.

**Step 2.** In the SGM+ app, log in with the email “kevin.keene@pnnl.gov” and the password “pnnlHBI20”.

**Step 3.** Power on the device with the switch shown in the left screenshot so that blue light is illuminated. Slide the covering to the left to open the aperture so that it shows white, shown in right screenshot.

Power switch

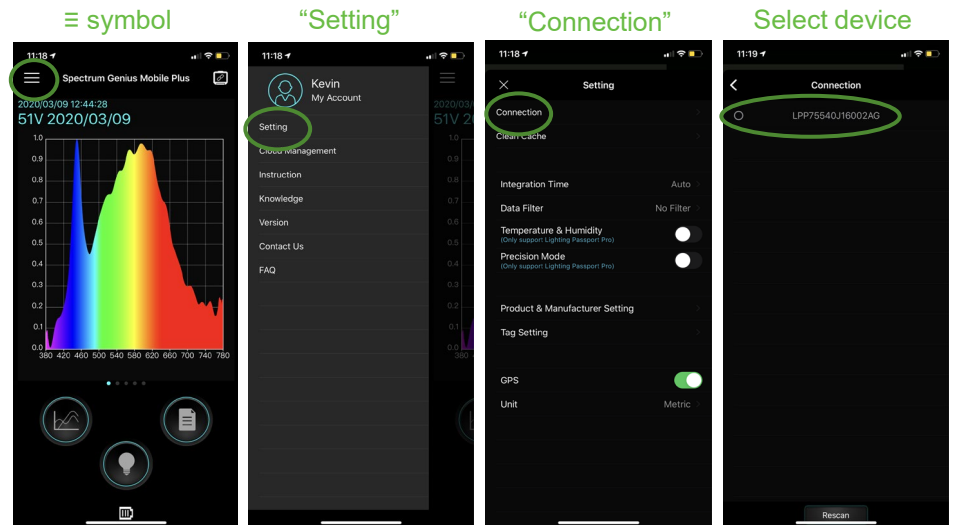


Left to right: blue light, aperture slide, aperture



## Appendix C

**Step 4.** With Bluetooth enabled on your mobile device, pair to Lighting Passport by clicking the ≡ symbol in the upper left then “Setting”, then “Connection”, then the device once it appears. See screenshots.



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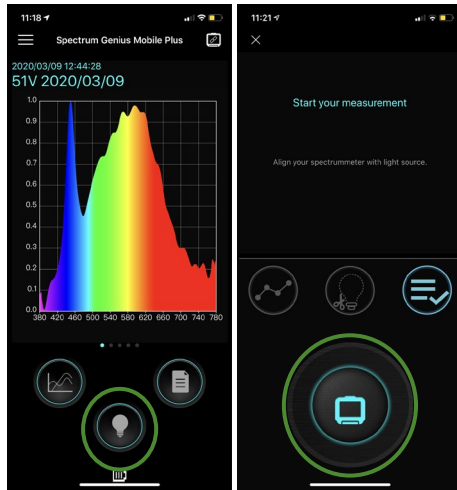
## Appendix C

### Step 5. Take practice lighting measurements.

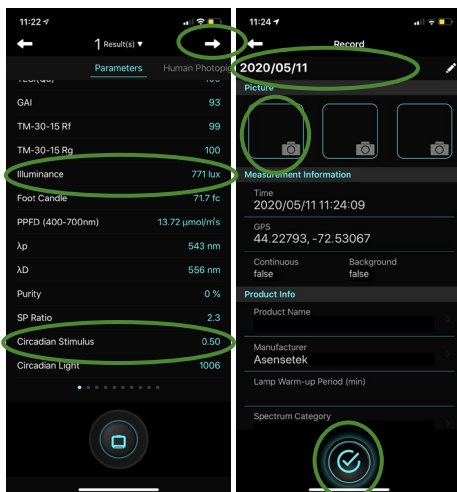
- A. First point the lighting passport aperture in the correct direction.
  - a) For horizontal illuminance, this should be on a horizontal surface (e.g. desk/table) pointing toward the ceiling for horizontal illuminance.
  - b) For circadian stimulus, it should be facing forward, in direction of eyesight of the theoretical occupant, at eye level. A tripod can be used to standardize this, set at 43" above ground (for seated desks).
- B. Be sure that your shadow is not interfering with the device.
- C. Leave task lighting and overhead lights on and any window blinds open.

Need action  
shot,  
zoomed it

## Appendix C



Button at bottom



- D. Press the lightbulb symbol on the main screen, then the button at the bottom to take the measurement (see screenshot).
- E. Record the “Illuminance” value if doing horizontal illuminance or the “Circadian Stimulus” value for CS on a pad and paper or in a digital spreadsheet.
- F. Save the measurement for back up, if desired, by pressing the right arrow in the top right. Enter a name for the measurement that includes the location (Room # for example and zone) and whether it’s CS or horizontal illuminance. Take a picture and add notes if desired. Press the button at bottom of screen to save.
- G. Repeat Step 5 with the other measure (horizontal illuminance or circadian stimulus).

# Appendix C

**Step 6.** Proceed to each measurement location and take a reading of both horizontal illuminance and circadian stimulus. See Appendix A for selecting locations. For window locations, take four readings on separate days to account for weather and average. Record CS and horizontal illuminance as well as the zone, room and space type in “Spot Data” tab of Excel tool.

	A	B	C	D	E	F	G	H	I	J
1	Circadian Stimulus	PM2.5 (mg/m3)	PM10 (mg/m3)	Horizontal Illuminance (lux)	Space Type	Room	Zone			
2										Warning Messages
3	0.26	0.002	0.002	771	Open Office	Lab	Floor 1 North			1
4										2
5	0	0.001	0.001	3	Open Office	D18	Floor 1 North			3
6	0.01	0.001	0.002	22	Open Office		Floor 1 North			4
7	0.11	0.001	0.001	347	Open Office	E14	Floor 1 North			5 You have entered a Space Type that is not Open Office, Enclosed Office
8	0	0.001	0.002	534	Open Office	A06	Floor 1 North			6
9	0	0.001	0.004	895	Open Office	A06	Floor 1 North			
10	0	0.001	0.003	588	Open Office	A06	Floor 1 North			
11	0.2	0.001	0.002	981	Conference Room	A06	Floor 1 North			
12										
13	0.22	0.003	0.002	651	Open Office	Lab	Floor 1 North			
14	0.19	0.001	0.003	400	Enclosed Office		Floor 1 North			
15	0.01	0.001	0.002	210	Open Office		Floor 1 North			
16	0	0.001	0.002	3	Open Office		Floor 1 North			
17	0.01	0.001	0.002	92	Conference Room	E14	Floor 1 North			
18	0.1	0.001	0.003	397	Open Office	A06	Floor 1 North			
19	0.2	0.001	0.001	473	Open Office	A06	Floor 1 North			
20	0.1	0.001	0.002	956	Open Office	A06	Floor 1 North			
21										
22										
23	0.24	0.002	0.005	1192	Enclosed Office	D36D	Floor 1 North			
24										
25										
26										
27										
28	0	0.001	0.002	387	Open Office	A06	Floor 1 South			
29	0	0.001	0.001	614	Open Office	A06	Floor 1 South			

Warning messages may appear in column J if your data is outside the typical or acceptable values.

Technical note—do not drag cells to move data as it will interfere with the formulas. You must type over or copy and paste.

# Appendix D

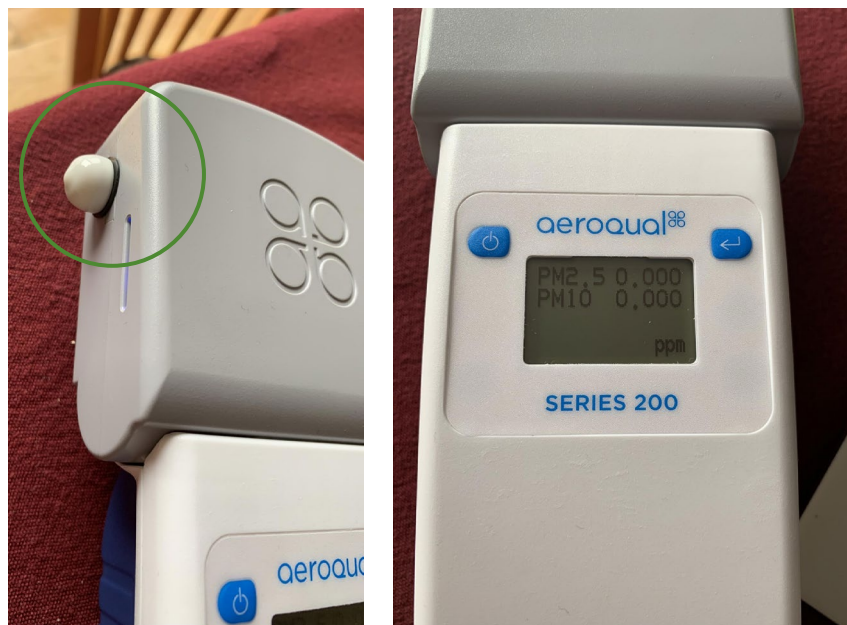
## Aeroqual Series 200 Set Up

## Appendix D

**Step 1.** Power on device by holding the power button and wait 3 minutes to warm up.

**Step 2.** Remove the white cap from the left side of the device so that the inlet is exposed.

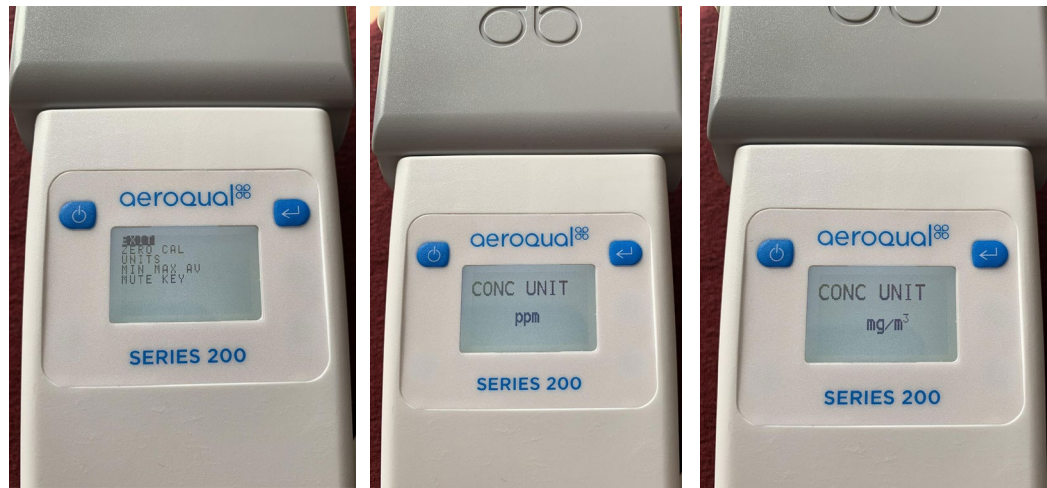
**Step 3.** The values for both PM10 and PM2.5. are displayed on the main screen. Wait to settle before recording a measurement. The device does not store or log any data.





## Appendix D

**Step 4.** Default units are ppm. Change units to mg/m<sup>3</sup> by pressing the left arrow key to get to the menu screen, then press the power key to scroll down to “UNITS”, press the left arrow key to select, press the power key to change to mg/m<sup>3</sup>, then the left arrow key to confirm. Return to main screen using power key to scroll to “EXIT”, then left arrow key to select.



# Appendix D

**Step 5.** Proceed to each measurement location and take a reading of both PM2.5 and PM10. See Appendix A for selecting locations. Record values as well as the zone, room and space type in “Spot Data” tab of Excel tool.

	A	B	C	D	E	F	G	H	I	J
1	Circadian Stimulus	PM2.5 (mg/m3)	PM10 (mg/m3)	Horizontal Illuminance (lux)	Space Type	Room	Zone			
2										Warning Messages
3	0.26	0.002	0.002	771	Open Office	Lab	Floor 1 North			1
4										2
5	0	0.001	0.001	3	Open Office	D18	Floor 1 North			3
6	0.01	0.001	0.002	22	Open Office		Floor 1 North			4
7	0.11	0.001	0.001	347	Open Office	E14	Floor 1 North			5 You have entered a Space Type that is not Open Office, Enclosed Office
8	0	0.001	0.002	534	Open Office	A06	Floor 1 North			6
9	0	0.001	0.004	895	Open Office	A06	Floor 1 North			
10	0	0.001	0.003	588	Open Office	A06	Floor 1 North			
11	0.2	0.001	0.002	981	Conference Room	A06	Floor 1 North			
12										
13	0.22	0.003	0.002	651	Open Office	Lab	Floor 1 North			
14	0.19	0.001	0.003	400	Enclosed Office		Floor 1 North			
15	0.01	0.001	0.002	210	Open Office		Floor 1 North			
16	0	0.001	0.002	3	Open Office		Floor 1 North			
17	0.01	0.001	0.002	92	Conference Room	E14	Floor 1 North			
18	0.1	0.001	0.003	397	Open Office	A06	Floor 1 North			
19	0.2	0.001	0.001	473	Open Office	A06	Floor 1 North			
20	0.1	0.001	0.002	956	Open Office	A06	Floor 1 North			
21										
22										
23	0.24	0.002	0.005	1192	Enclosed Office	D36D	Floor 1 North			
24										
25										
26										
27										
28	0	0.001	0.002	387	Open Office	A06	Floor 1 South			
29	0	0.001	0.001	614	Open Office	A06	Floor 1 South			

Warning messages may appear in column J if your data is outside the typical or acceptable values.

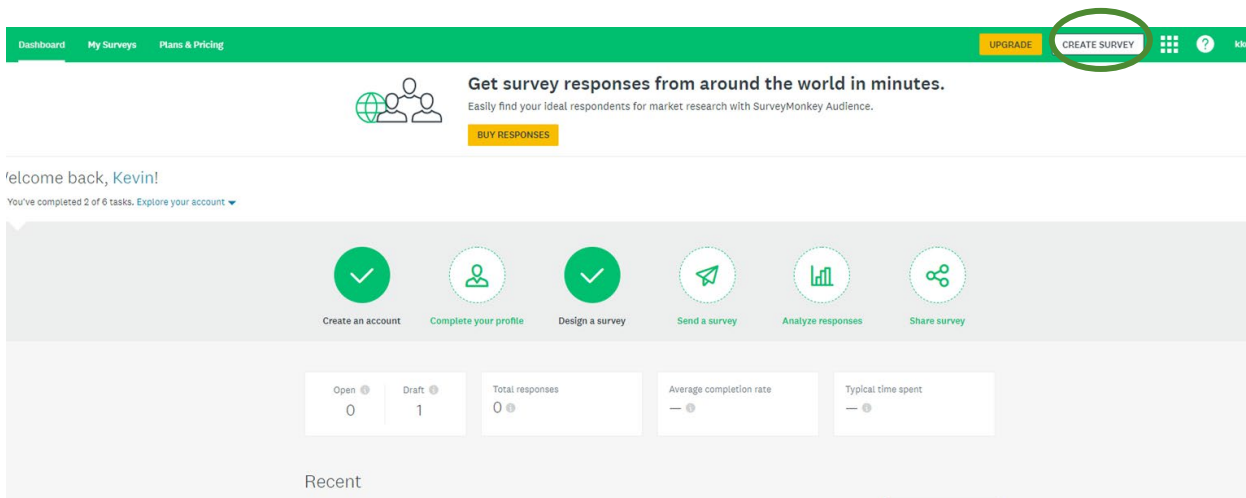
Technical note—do not drag cells to move data as it will interfere with the formulas. You must type over or copy and paste.

# Appendix E

## Occupant Survey Set Up, Deployment, and Results

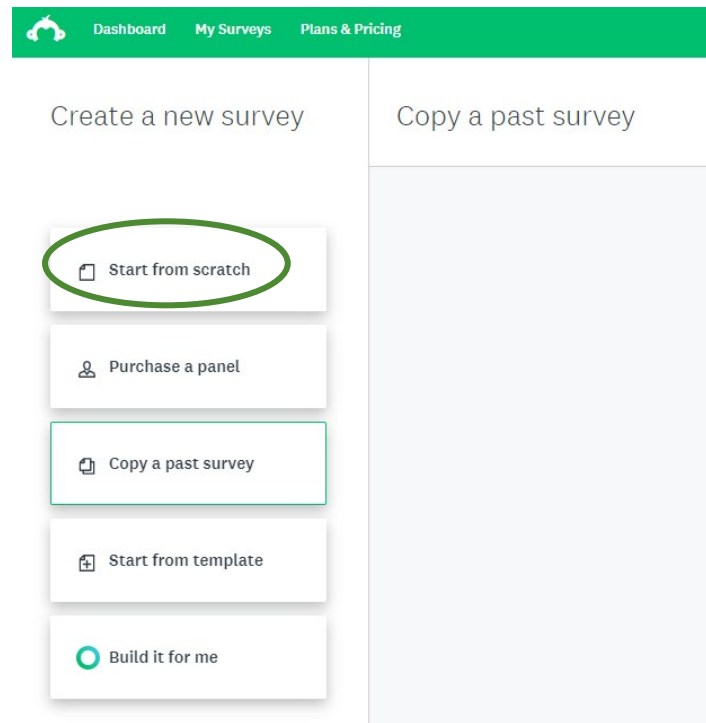
# Appendix E

**Step 1.** Click on “Create Survey” in the upper right corner at [surveymonkeys.com/dashboard](https://surveymonkeys.com/dashboard).



## Appendix E

**Step 2.** Click on “Start from Scratch” on the left-side menu.



## Appendix E

**Step 3.** Enter the name you want to call your survey and check the box “My questions are already written”. Select “Use my own contacts” and choose which survey format you prefer.

The screenshot displays a survey creation form titled "Name your survey". The form includes the following elements:

- A text input field for "Survey name" (highlighted with a green circle).
- A dropdown menu for "Survey category" (highlighted with a green circle).
- A checkbox labeled "My questions are already written." which is checked (highlighted with a green circle).
- Radio buttons for "Choose how to collect responses": "Purchase a panel" (unselected) and "Use my own contacts" (selected).
- Three survey format options under "Choose a survey format (Optional)":
  - "One question at a time" (selected with a green checkmark): Automatically scroll to the next question.
  - "Classic": Show all questions on a page at once.
  - "Conversation BETA": Turn your survey into a chat conversation.
- A green "CREATE SURVEY" button at the bottom right.

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## Appendix E

**Step 4.** Copy and paste the following 10 questions into the text box that appears. Be sure to leave a line break between each question. Click “Add (10) Questions” when you are done.

1. In a typical week, approximately what portion of your work time do you spend at the locations listed below? Your total time must equal 100%.
  - a. % at your desk in your primary work location:
  - b. % in conference/meeting rooms in your primary work location:
  - c. % working from home:
  - d. % at other locations (client locations, other buildings on campus, work travel):
2. When working in your primary work location, what kind of individual workspace do you primarily use?
  - a. An enclosed single-person office
  - b. An enclosed multi-person office
  - c. A workspace or cubicle where all dividers are high enough that you cannot see over when standing
  - d. A workspace or cubicle with some dividers that you cannot see over when seated
  - e. Open workspace with no dividers or dividers that you can see over when seated
  - f. None of the above
3. Please indicate your typical state of comfort in your primary workspace for each season. Please select NA if you do not work during that season, have not worked during that season yet, or cannot remember.
  - a. Spring
  - b. Summer
  - c. Autumn
  - d. Winter

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## Appendix E

4. Which of the following air quality issues do you experience in your primary workspace. Select all that apply.
- a. Odor
  - b. Stuffiness
  - c. Too dry
  - d. Too humid
  - e. Dust or allergens
  - f. None
5. How satisfied are you with the electric (overhead and task) lighting in your primary workspace?
- a. Very dissatisfied
  - b. Somewhat dissatisfied
  - c. Neither satisfied nor dissatisfied
  - d. Somewhat satisfied
  - e. Very satisfied
6. Which of the following electric lighting issues do you experience in your primary workspace? Select all that apply.
- a. Too dim
  - b. Too bright
  - c. Too much glare or contrast
  - d. Automatic lighting turns off, on, or dims when not desired
  - e. Undesirable light color (too cold/blue, too warm/orange, etc.)
  - f. None
7. How satisfied are you with the daylight in your primary workspace?
- a. Very dissatisfied
  - b. Somewhat dissatisfied
  - c. Neither satisfied nor dissatisfied
  - d. Somewhat satisfied
  - e. Very satisfied



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## Appendix E

8. Does your primary workspace have window(s) that provide daylight?

- a. Yes, my primary workspace has a window that provides daylight that I can view while seated
- b. My primary workspace does have some daylight, but my view of the window is partially obstructed/blocked while seated
- c. My primary work area has daylight, but my view of the window is completely blocked while seated
- d. No, my workspace does not have a window and there is no daylight nearby

9. How satisfied are you with the control for glare from daylight in your primary workspace?

- a. Very dissatisfied
- b. Somewhat dissatisfied
- c. Neither satisfied nor dissatisfied
- d. Somewhat satisfied
- e. Very satisfied

10. Please provide any additional comments concerning your overall satisfaction with your primary workspace that relate to your overall productivity and comfort.

## Appendix E

**Step 5.** Hover over the first question and click “Edit.” Click the dropdown arrow to the right of “Multiple Choice” and click “Multiple Textboxes”.

The screenshot displays a quiz editor interface. At the top, there are navigation tabs: EDIT (highlighted in green), OPTIONS, LOGIC, MOVE, and COPY. Below the tabs, a question titled "Q1" is shown with the text: "In a typical week, approximately what portion of your work time do you spend at the locations listed below? Your total time must equal 100%." To the right of the question text is a dropdown menu currently set to "Multiple Choice". A dropdown arrow is visible to the right of the menu. The dropdown menu is open, showing a list of question types: Multiple Choice, Checkboxes, Star Rating, Single Textbox, Comment Box, Matrix of Dropdown Menus, Dropdown, Matrix / Rating Scale, Ranking, Slider, Multiple Textboxes (highlighted with a green circle), and Date / Time. Below the question text, there are four input fields with radio buttons, each representing a location: "% at your desk in your primary work location: .....", "% in conference/meeting rooms in your primary work location: .....", "% working from home: .....", and "% at other locations (client locations, other buildings on campus, work travel): ....." At the bottom of the interface, there are three checkboxes: "Score this question (enable quiz mode)", "Use previous answer choices (carry forward responses)", and "Add an 'Other' Answer Option or Comment Field".

## Appendix E

**Step 6.** Check the “Only Allow Numerical Data” box and the “Require a Fixed Sum” box. Enter “100” next to “Sum of All Answers”. Click “Save” in the bottom right.

Label 3 % working from home: \_\_\_\_

Label 4 % at other locations (client locations, other buildings on campus, work travel): \_\_\_\_

⊕ BULK ANSWERS ?

Only Allow Numerical Data ?  Require a Fixed Sum ?

Use previous answer choices (carry forward responses) ?

Customize Number Validation Message ?

When an answer is not a number, display this error message.

Please enter a number. Decimals, percentages, and non-numeric characters are not accepted.

Require a Fixed Sum ?

Sum of all Answers = 100

When the answers do not add up correctly, display this error message.

The choices need to add up to [enter sum here].

⊕ NEXT QUESTION CANCEL SAVE

## Appendix E

**Step 7.** Hover over question 3 and click “Edit”. Click the dropdown arrow next to “Multiple Choice” and click “Matrix/ Rating Scale”.

The screenshot displays a quiz editor interface. At the top, there are tabs for 'EDIT', 'OPTIONS', 'LOGIC', 'MOVE', and 'COPY'. The 'EDIT' tab is active. Below the tabs, a question titled 'Q1' is shown: 'In a typical week, approximately what portion of your work time do you spend at the locations listed below? Your total time must equal 100%.' The question type is currently set to 'Multiple Choice'. A dropdown menu is open, showing various question types: Multiple Choice, Checkboxes, Star Rating, Single Textbox, Comment Box, Matrix of Dropdown Menu, Dropdown, Matrix / Rating Scale (highlighted with a green circle), Ranking, Slider, Multiple Textboxes, and Date / Time. Below the question, there are four radio button options for work locations: '% at your desk in your primary work location: .....', '% in conference/meeting rooms in your primary work location: .....', '% working from home: .....', and '% at other locations (client locations, other buildings on campus, work travel): .....'. At the bottom, there are checkboxes for 'Score this question (enable quiz mode)', 'Use previous answer choices (carry forward responses)', and 'Add an "Other" Answer Option or Comment Field'.

## Appendix E

**Step 7.** Add six columns with the names “Too warm”, “Somewhat too warm”, “Comfortable”, “Somewhat too cool”, “Too cool”, and “NA”. Uncheck “Use Weights” and “Forced Ranking”. Click “Save”.

Winter

BULK ANSWERS

Use previous answer choices (carry forward responses) UPGRADE

**Columns**

Too warm

Somewhat too warm

Comfortable

Somewhat too cool

Too cool

NA

Forced ranking (one response per column)

Add an "Other" Answer Option for Comments

NEXT QUESTION CANCEL SAVE

## Appendix E

**Step 8.** For questions 4 and 6, go to “Edit” and click the dropdown arrow next to “Multiple Choice” and click “Checkboxes”. Click “Save” in the bottom right.

The screenshot displays a question editor interface. At the top, there are tabs for 'EDIT', 'OPTIONS', 'LOGIC', 'MOVE', and 'COPY'. A warning message is visible: 'Warning: Some previously entered data isn't compatible with your new question type and will not be saved to it.' The question being edited is 'Q5: Which of the following air quality issues do you experience in your primary workspace. Select all that apply.' The question type is currently set to 'Multiple Choice'. A dropdown menu is open, showing various question types: 'Multiple Choice', 'Checkboxes', 'Star Rating', 'Single Textbox', 'Comment Box', 'Matrix of Dropdown Menus', 'Dropdown', 'Matrix / Rating Scale', 'Ranking', 'Slider', 'Multiple Textboxes', and 'Date / Time'. The 'Checkboxes' option is highlighted with a green circle. Below the question, there is an 'Answer Genius' section and a list of options with radio buttons: 'Odor', 'Stiffness', 'Too dry', 'Too humid', 'Dust or allergens', 'None', and 'Other, please specify: ...'. At the bottom right, there is a 'BULK ANSWERS' button.

## Appendix E

**Step 9.** For each question except number 10, click “Options”. Select the box “Require an Answer to This Question”.

EDIT   **OPTIONS**   LOGIC   MOVE   COPY

Require an Answer to This Question ?

Display this error message when this question is not answered.

This question requires an answer.

Change the Layout for How Choices are Displayed ?

Randomize, Sort, or Flip Choices ?

Adjust Question Layout ?

Enable Question Text A/B Test (Random Assignment) ?

**⊕ NEXT QUESTION**   **CANCEL**   **SAVE**


## Appendix E

**Step 11.** Go to the “Collect Responses” tab at the top and click “Send surveys your way”. Click “Get weblink”.

Workplace Survey


SUMMARY → DESIGN SURVEY → PREVIEW & SCORE → **COLLECT RESPONSES** → ANALYZE RESULTS → PRESENT RESULTS

How would you like to collect responses to your survey?



**Send surveys your way**

Send your surveys by email, embed them on your website, share a link on social media or a web page, and more.



**Target your ideal respondents**

Buy responses from the right demographics on our global survey panel, SurveyMonkey Audience. Get results in minutes.



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## Appendix E

**Step 12.** Send the following draft email to the building email list. Insert the survey link from the website and give the occupants 1-2 weeks to complete the survey. Put the name and email of a contact person. Send a reminder email one day before closing the survey.

Dear building occupant,

You have been selected to participate in a research study for the purpose of investigating occupant comfort, satisfaction, and productivity in federal buildings. The objective of this survey is to collect building-related data that will be used to evaluate occupant comfort with respect to temperature, indoor air quality, and lighting.

The survey, which is completely anonymous and voluntary, will take about 3 minutes to complete.

**You can access the survey here:** <insert link>

**The survey will close** <day, month, year>

If you have any questions, please contact <contact name, email>

## Appendix E

**Step 13.** When the survey period is finished, return to the survey on the website and proceed to the “Analyze Results” tab. Use the tables on this page to fill in the “Survey Data” tab in the Healthy Building Excel Tool. Question 10 if for your own information and is not used in the Tool.

