

Healthy Buildings Toolkit Data Collection Guide

Pacific Northwest National Laboratory (PNNL)

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Overview

Healthy Buildings Toolkit Overview

- The Healthy Buildings Toolkit contains resources that facilitate decision making relating to building upgrades that promote energy efficiency and occupant productivity and wellbeing.
- This training document is intended to guide toolkit users to collect data, enter it into the accompanying **Healthy Buildings and Energy Support Tool (H-BEST)**, and interpret the results.
- The results are twofold:
 1. *Quantitative Benefits* – H-BEST will calculate the financial gains relating to productivity improvement and other non-monetary benefits for 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, H-BEST will help the user identify appropriate operational modifications and equipment upgrades to improve indoor environmental quality (IEQ).

FEMP Healthy Buildings Resources

- The following resources are available to facilitate adoption of H-BEST and the toolkit:
 - [PNNL Healthy Building Website](#)
 - [HBI Factsheet](#)
 - [Healthy Building Resources Overview](#)
 - Pilot Study Reports
 - [GSA Pilot Study](#)
 - [PNNL Pilot Study](#)
 - [Fort Worth, TX Pilot Study](#)

Questions about the H-BEST and data collection?

Contact: healthy-buildings@pnnl.gov

H-BEST Outputs and Inputs

OUTPUTS

Estimated Human Benefits

- Productivity
- Satisfaction
- Sleep Quality
- Reduced Sick Leave

Cost-Benefit Analysis

- Energy Savings
- Retrofit Cost
- Personnel Savings

Improvement Recommendations

REQUIRED INPUTS TO OBTAIN EACH OUTPUT

1. IEQ Data

- Lighting
- Thermal Comfort
- Indoor Air Quality

1. IEQ Data

2. Yearly Modeled Energy Savings

3. Estimated Retrofit Cost

4. Personnel Information

1. IEQ Data

2. Occupant Survey

3. Diagnostic Information

H-BEST Inputs

Indoor Environmental Quality (IEQ)

-- This is collected with data loggers --

Indoor Air Quality	Carbon Dioxide (CO ₂)
	Particulate Matter (PM _{2.5})
	Total Volatile Organic Compounds (TVOC)
Thermal Comfort	Temperature
	Humidity
Lighting	Horizontal Illuminance
	Circadian Stimulus (CS) or Vertical Illum.

Supplementary Information

Cost and energy savings related to improvement

Personnel Information

Total Employees

Average Cost of Employee *

Occupant Survey

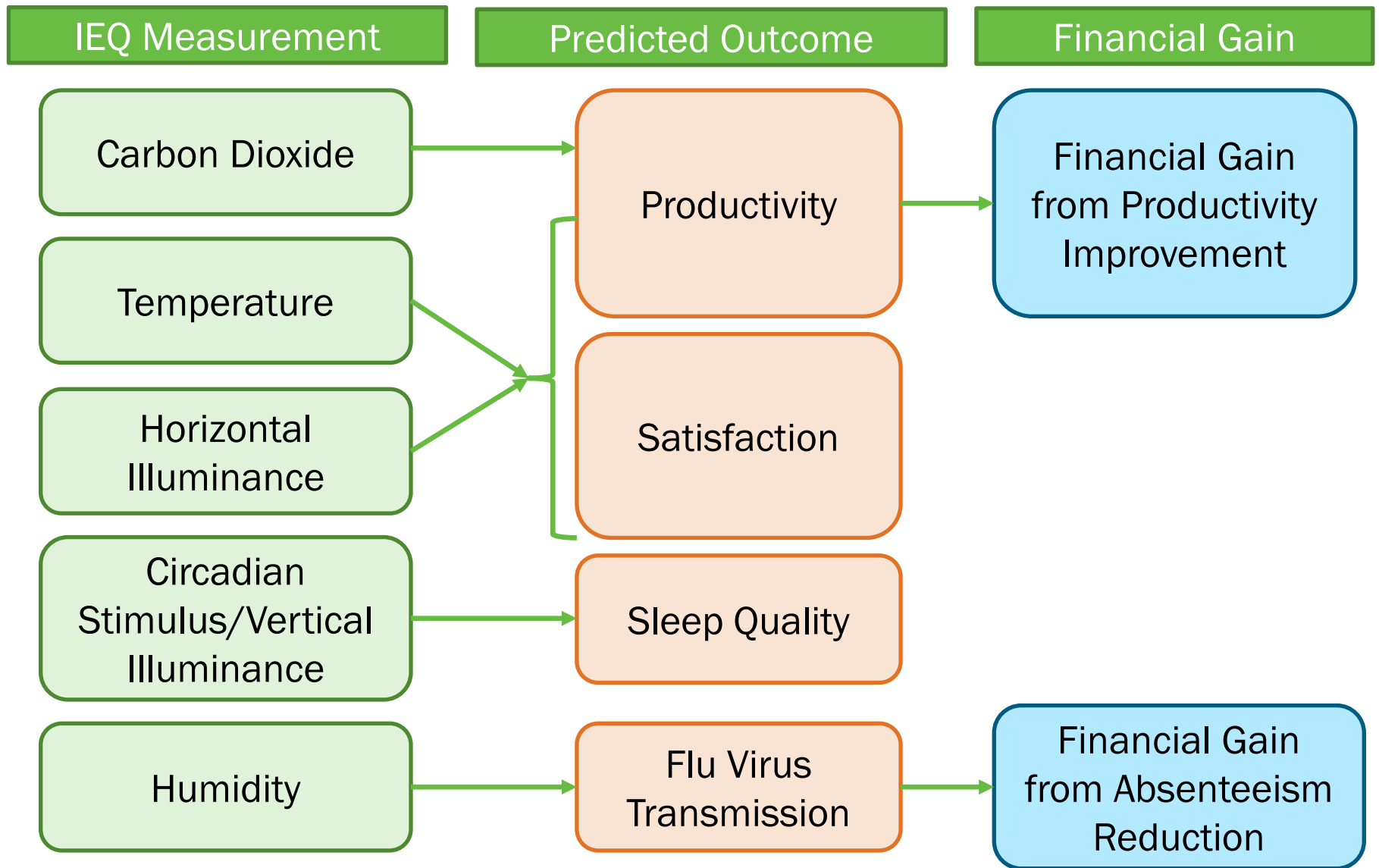
Survey template provided with 10 questions about satisfaction with IEQ

Diagnostic Information

Depending on identified IEQ issues, subset of 21 building system questions

* Defaults based on location if building-specific information is not available

IEQ Correlations in H-BEST



H-BEST Outputs and Interpretation

- **Estimated Human Benefits and Cost-Benefit Analysis**
 - Compare categories and get an idea of the magnitude of savings potential

Hypothetical Results:

Table 1. Financial and non-monetary benefits of improving IEQ (thousands \$USD).

	Health		Energy	Costs	Net Savings		Non-Monetary	
	Productiv. Gain	Expected NPV	Expected NPV	Capital + Cert. Cost	Expected NPV	Benefit / Cost Ratio	Sleep Gain (min)	Satisfaction Gain
IAQ	0.35%	\$292	\$4	\$0	\$296	N/A	N/A	N/A
Thermal Comfort	0.32%	\$273	\$3	-\$100	\$175	2.8	N/A	1.3%
Lighting	3.50%	\$2,921	\$2	-\$70	\$2,852	41.7	0.0	1.5%
Combined	4.17%	\$3,485	\$5	-\$170	\$3,320	20.5	0.0	2.7%

H-BEST Outputs and Interpretation

- Solutions development tab contains 72 possible improvement measures
- H-BEST will filter out the ones that are not applicable and the user can read the provided information to select the best options

Step 7. Improvement Opportunities

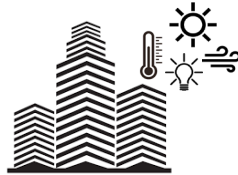
Return to Instructions Energy and Cost Results

User selects "YES" for the improvements they are interested in

7. Use the filter in the "Suggested" to select rows with "YES". The YES and NO values are automatically filled based on the "Selected" column. These improvement measures will then populate into your report on the "Results" tab.

ch improvement measure and then choose up

Improvement Measure	Suggested	IEQ Category	Selected	Issue and Solution	Applicability	Guidance
Ventilation schedule	NO	Carbon Dioxide	NO	CO ₂ could be improved during certain hours of day/week in at least one HVAC zone.		Install modulation damper at outdoor air intake (if not already present) and adjust ventilation schedule according to problematic times or use demand control ventilation (DCV).
Re-tune HVAC controls	YES	Carbon Dioxide	NO	CO ₂ could be improved in at least one HVAC zone. Important to test controls and verify their functionality before trying other solutions. The air distribution effectiveness can be improved and the HVAC has not been tested in some time. If the static fan pressure is too low or the distribution nozzle type/damper position limits flow too much, the air won't be discharged at a velocity in the space to facilitate effective air distribution and if the pressure is too high or the nozzle type/damper position ejects air too rapidly, it can affect their thermal comfort of occupants (too cold).		Improve air distribution by removing obstructions blocking diffuser type (increasing air velocity) or increasing fan speed for better throughout space.
Test and balance HVAC system for air circulation	YES	Carbon Dioxide	NO	CO ₂ could be improved in at least one HVAC zone. The ventilation may be below par.		Increase outdoor air fraction at indoor airtake to 30-60% CFM/person). Note that this could have impacts to PM levels if not sufficient and maintained.
Increase outdoor air	YES	Carbon Dioxide	NO	CO ₂ could be improved in at least one user-defined zone. The air distribution effectiveness can be improved and the HVAC has not been tested in some time.		Improve air distribution by removing obstructions blocking diffuser type (increasing air velocity) so that air can circulate. Note that other zones may have opportunity for improved air distribution as well but good CO ₂ .
Improve air circulation in select zones	YES	Carbon Dioxide	NO	CO ₂ could be improved during certain hours of day/week in at least one user-defined zone.	Reliable return air on floor CO ₂ sensors, fully modulating economizers	DCV uses feedback from indoor air quality sensors to determine outdoor air damper position. Make a corresponding lower outdoor air damper commands or airflow setpoints. CO ₂ sensors should be faulted. Implement a fault tolerant strategy—don't implement the outdoor air dampers to 0% or 100% indefinitely. Place



1. Indoor Environmental Quality (IEQ) Data

Indoor Air Quality and Thermal Comfort

Metrics:

- Temperature
- Humidity
- Carbon Dioxide
- Particulate Matter (PM_{2.5})
- Total Volatile Organic Compounds (TVOCs)



This guide uses the [Kaiterra Sensedge](#) as an example for equipment that logs all the metrics above. This product is not endorsed by PNNL or DOE.

Image source: [orientalpureair.com](#)

- **Duration: one to two typical work weeks per location.**
 - One measurement every ~15 minutes.
 - Choose a timeframe with typical occupancy (e.g., not during winter holidays).
 - Recommended to repeat for each season for comprehensive analysis.
- **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 more details on selecting locations.

Lighting

Metrics:

- Horizontal Illuminance
- Vertical Illuminance



This guide uses the [LI-COR LI-210R-BNC-5](#) sensor as an example for equipment that logs illuminance. This product is not endorsed by PNNL or DOE.
Image source: licor.com

- **Horizontal illuminance is the light hitting a horizontal surface (e.g. desk) and is a metric for visual performance.**
- **Vertical illuminance is the light hitting a vertical surface (e.g., wall) and is indicative of circadian (24-hr biological cycle) performance.**
 - This is because vertical illuminance is representative of the light that enters the eye of an occupant who is looking forward at a workstation.
 - The vertical illuminance measurements will be filtered out for 9AM-1PM, which is the critical timeframe for someone on a typical sleep schedule to receive circadian stimulus.

Lighting

Metrics:

- Horizontal Illuminance
- Vertical Illuminance



This guide uses the [LI-COR LI-210R-BNC-5](#) sensor as an example for equipment that logs illuminance. This product is not endorsed by PNNL or DOE.
Image source: licor.com

- **Sample size: 8 locations per 50k sq.ft.**
 - Each location will have one sensor facing upward to measure horizontal illuminance, one sensor mounted to measure vertical illuminance, and one logger which will connect to the two sensors.
 - Variety of spaces (floors, wings, lighting fixture types, etc.).
 - Only in conference rooms, enclosed offices, and open offices.
- **Duration: 1 day for core, 1 week for perimeter.**
 - Windows and daylight will cause daily variation and these locations should be measured over one week.
 - Interior spaces should have constant lighting conditions and can be measured for one day.

Metrics:

- Horizontal Illuminance
- Vertical Illuminance



This guide uses the [LI-COR LI-210R-BNC-5](#) sensor as an example for equipment that logs illuminance. This product is not endorsed by PNNL or DOE.
Image source: licor.com

- **Placement: place the sensors to reflect the occupants' experience.**
 - Choose a representative location that reflects window proximity and color of nearby surfaces.
 - Best practice is to ignore spaces that occupants make intentionally dark or dim out of preference.
 - Occupancy sensors can affect lighting performance and make it appear as if conditions are worse than they are. Choose a location that will be occupied during business hours or avoid spaces with occupancy sensors.
 - See Appendix A for more details on selecting locations.



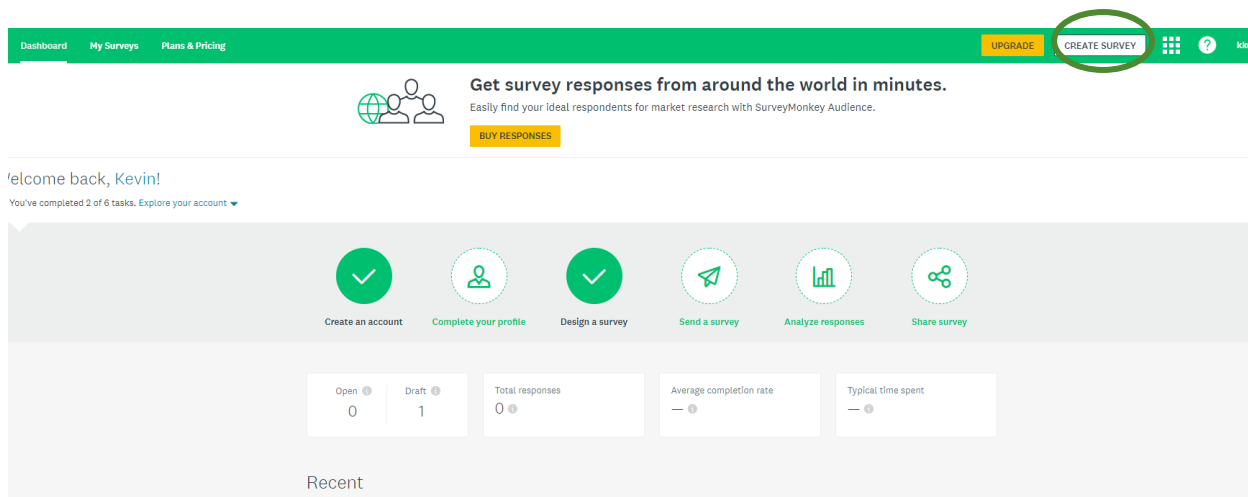
2. Occupant Survey

Occupant Survey

- The survey collects information about occupant satisfaction that will be used to help identify specific improvement recommendations.
- [SurveyMonkey](#) is used in this guide as an example 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 H-BEST's inputs.
- The survey can be sent via a building email list with a one- to two-week timeframe for responses.
- The following slides give step-by-step instructions on how to set up, deploy, and collect the results of a survey using SurveyMonkey.

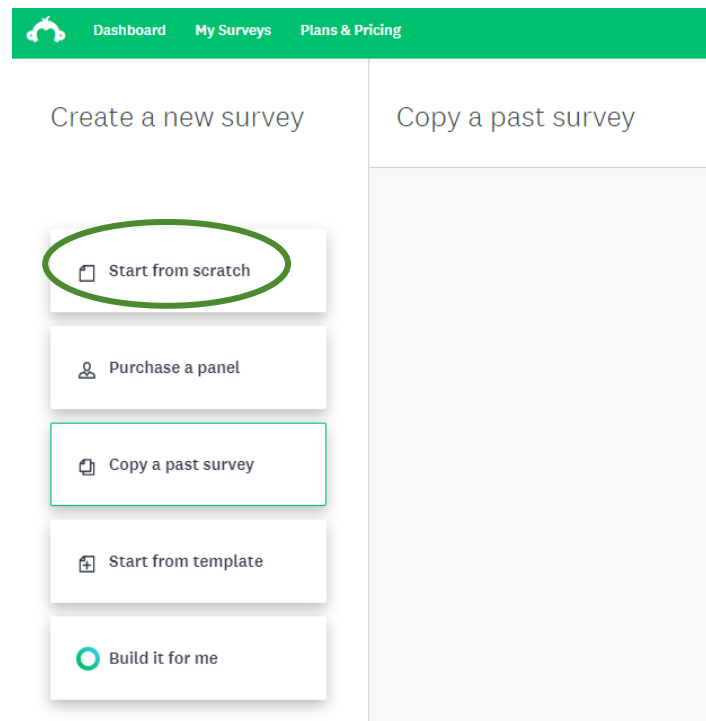
Occupant Survey

Step 1. Click on “Create Survey” in the upper right corner at surveymonkey.com/dashboard.



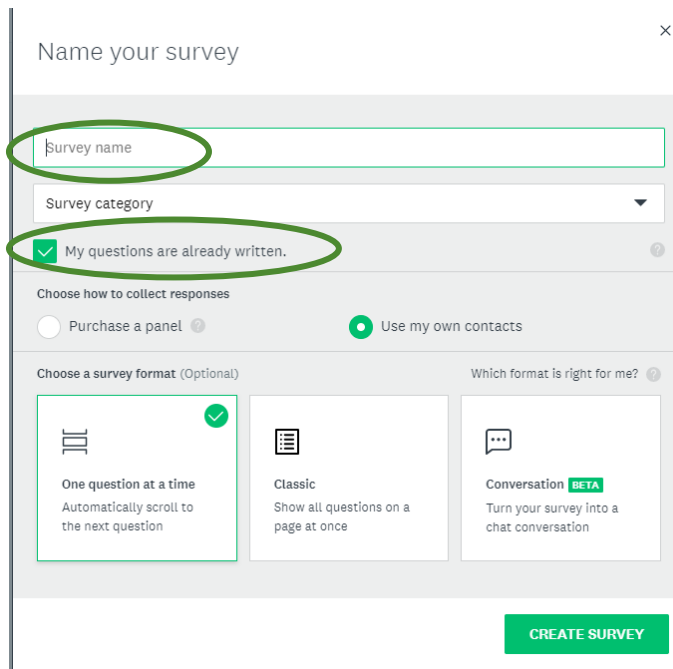
Occupant Survey

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



Occupant Survey

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 shows a form titled "Name your survey" with a close button (X) in the top right corner. The form contains the following elements:

- A text input field labeled "Survey name" which is circled in green.
- A dropdown menu labeled "Survey category".
- A checked checkbox labeled "My questions are already written." which is also circled in green.
- A section titled "Choose how to collect responses" with two radio buttons: "Purchase a panel" (unselected) and "Use my own contacts" (selected).
- A section titled "Choose a survey format (Optional)" with a sub-question "Which format is right for me?". It contains three options:
 - "One question at a time" with the subtext "Automatically scroll to the next question". This option is highlighted with a green border and a green checkmark.
 - "Classic" with the subtext "Show all questions on a page at once".
 - "Conversation" with a "BETA" tag and the subtext "Turn your survey into a chat conversation".
- A green "CREATE SURVEY" button at the bottom right.

Occupant Survey

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

Occupant Survey

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

Occupant Survey

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.

Occupant Survey

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 shows a survey editor interface with a top navigation bar containing 'EDIT', 'OPTIONS', 'LOGIC', 'MOVE', and 'COPY'. The 'EDIT' tab is active. Below the navigation bar, there is a question titled 'Q1' 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 menu is open, showing various question types: Multiple Choice (checked), Dropdown, Matrix / Rating Scale, Ranking, Slider, Multiple Textboxes (highlighted with a green circle), Date / Time, Checkboxes, Star Rating, Single Textbox, Comment Box, and Matrix of Dropdown Menus. 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 of the editor, 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'.

Occupant Survey

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.

The screenshot displays the configuration interface for a survey question. At the top, there are two labels: "Label 3" with the text "% working from home:" and "Label 4" with the text "% at other locations (client locations, other buildings on campus, work travel):". Below these is a section titled "BULK ANSWERS" with a plus icon and a help icon. Two checkboxes are checked and circled in green: "Only Allow Numerical Data" and "Require a Fixed Sum". Below these is a section for "Use previous answer choices (carry forward responses)" which is unchecked. The "Customize Number Validation Message" section contains a text area with the message: "Please enter a number. Decimals, percentages, and non-numeric characters are not accepted." The "Require a Fixed Sum" section has a text input field containing "100" next to the label "Sum of all Answers =". Below this is another text area for a custom error message: "The choices need to add up to [enter sum here].". At the bottom, there are three buttons: "NEXT QUESTION" (with a plus icon), "CANCEL", and "SAVE".

Occupant Survey

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 survey 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", "Dropdown", "Matrix / Rating Scale" (highlighted with a green circle), "Ranking", "Slider", "Multiple Textboxes", "Date / Time", "Checkboxes", "Star Rating", "Single Textbox", "Comment Box", and "Matrix of Dropdown Menus". 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 of the interface, 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".

Occupant Survey

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”.

The screenshot displays the configuration interface for an occupant survey. At the top, there is a text input field containing "Winter" and a "BULK ANSWERS" section with a help icon. Below this is a yellow banner with the checkbox "Use previous answer choices (carry forward responses)" and an "UPGRADE" button. The main section is titled "Columns" and contains six text input fields with the following text: "Too warm", "Somewhat too warm", "Comfortable", "Somewhat too cool", "Too cool", and "NA". Each field has a set of control icons (+, -, and a circle with a slash) to its right. A rich text editor toolbar is visible over the "Somewhat too cool" field, and a dropdown menu "Insert text from..." is open below it. At the bottom of the column list, there are two checkboxes: "Forced ranking (one response per column)" and "Add an 'Other' Answer Option for Comments". Both checkboxes are currently unchecked. At the very bottom, there are three buttons: "NEXT QUESTION", "CANCEL", and "SAVE". Two green hand-drawn circles highlight the "Too warm" column name and the "Add an 'Other' Answer Option for Comments" checkbox.

Occupant Survey

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 the 'EDIT' tab of a survey editor. At the top, there are navigation tabs: 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 main question, Q5, asks: 'Which of the following air quality issues do you experience in your primary workspace. Select all that apply.' Below the question, there is a list of options with radio buttons: Odor, Stuffiness, Too dry, Too humid, Dust or allergens, None, and Other, please specify: A dropdown menu is open over the question, showing various question types. The 'Checkboxes' option is highlighted with a green circle. Other options in the menu include Multiple Choice, Dropdown, Matrix / Rating Scale, Star Rating, Ranking, Single Textbox, Slider, Comment Box, Multiple Textboxes, Matrix of Dropdown Menus, and Date / Time. At the bottom right of the editor, there is a 'BULK ANSWERS' button.

Occupant Survey

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**


Occupant Survey

Step 10. Go to the “Collect Responses” tab at the top and click “Send surveys your way”. Click “Get weblink”.

Workplace Survey

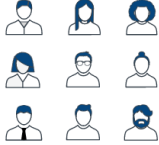
SUMMARY → DESIGN SURVEY → PREVIEW & SCORE → **COLLECT RESPONSES** → ANALYZE RESULTS → PRESENT RESULTS

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.

Occupant Survey

Step 11. 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.

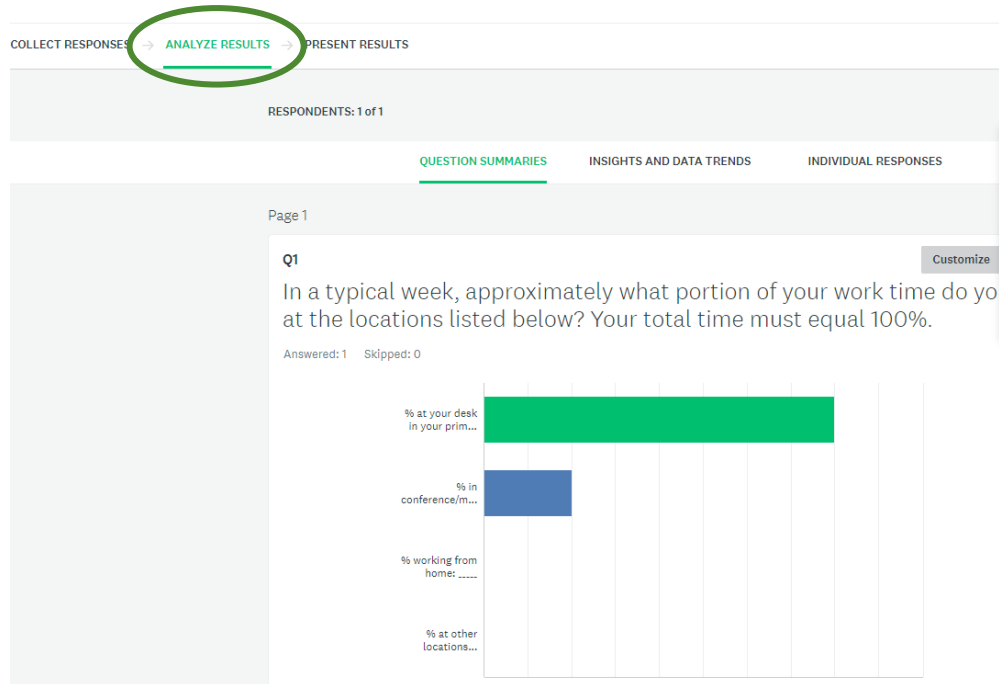
You can access the survey here: <insert link>

The survey will close <day, month, year>

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

Occupant Survey

Step 12. 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” tab in H-BEST. Question 10 if for your own information and is not used in the Tool.





3. Employee/Personnel Information

Employee/Personnel Information

- The following information is needed for input into H-BEST.

Metric	Notes
Number of Employees	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 by entering “1” for this field.
Average Cost of Employee (Salary + Benefits)	Can use the average salary x 1.3 for the approximate cost of the employees. See following slide for how to find a regional approximation for average salary if the exact average is not available from the human resources department or management.

Employee/Personnel Information



- 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 in which the building is located, and then average GS level and step for the building.
 - 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.¹
- Then press calculate to get the average adjusted salary for your location.

The screenshot shows the 'GS General Schedule Pay Calculator' interface. It features a blue header with the title. Below the header, there are three numbered steps: 1. 'What state do you work in?' with a map of the United States and a dropdown menu showing 'Washington'. 2. 'What county do you work in?' with a dropdown menu showing 'Benton County'. 3. 'What is your GS Paygrade and Step?' with two dropdown menus, the first showing 'GS-1' and the second showing 'STEP 1'. Below these steps is a dropdown menu for '2020 GS Pay Table'. At the bottom of the form is a large green button labeled 'Calculate My GS Pay'.

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

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



4. Diagnostic Information

Diagnostic Metrics Overview

- 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	Task Lighting
	Lighting Satisfaction	
	Complaints	Window Proximity
	Circadian Stimulus	
Daylight Satisfaction		
	Cubicle Height	
	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	
	HVAC testing and balancing	
	Carbon Dioxide	Air Distribution Effectiveness
VAV Boxes		
HVAC testing and balancing		
VOC (no baseline metric)	Green Cleaning Policy	
	Low-emitting Materials	
Thermal Comfort	Predictive Mean Vote	Personal Thermal Devices
	Temperature Satisfaction	Enclosure Heat Loss/Gain
	Seasonal Satisfaction	

Diagnostic Metrics Overview

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?		
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.		
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		

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

Diagnostic Metrics Overview

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?		TWS 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.		TWS 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.		TWS 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.		TWS 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 during occupied		TWS 2.1-4; LEED v4 EQ Low-Emitting Mat TWS 2.1-12; WELL A03 p1/ A06 p1
		atural features (e.g., at minimize direct		TWS 2.3-8; WELL L04 p1
		m exterior e 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. Carbon or combination carbon/particle filters with a mechanical efficiency rating		TWS 2.1-11

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

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?

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 CO₂ 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 CO₂)

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.

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.

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.

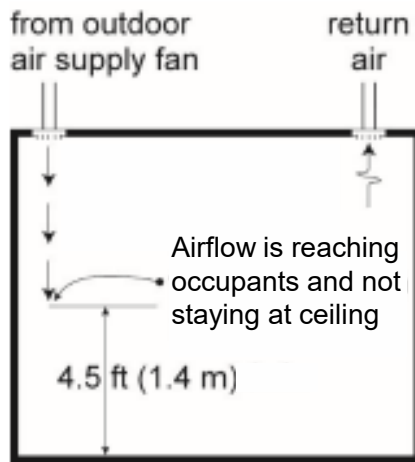
Carbon Dioxide

- The required carbon dioxide (CO₂) questions will depend on the results of the CO₂ 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
CO ₂	HVAC system has undergone testing and balancing at least once every 5 years.
CO ₂	What is the air distribution effectiveness (select from options)?
CO ₂	What type of ventilation system is used?
CO ₂	What is the ventilation rate (outdoor air supply) to the building during occupied hours?

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
- Example:



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

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 CO₂ levels to match occupancy.
 - Choose the response that best represents your building.

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 CO₂)

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.

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.

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. Illum.	Occupants have task lighting at their workstations.

Appendix A

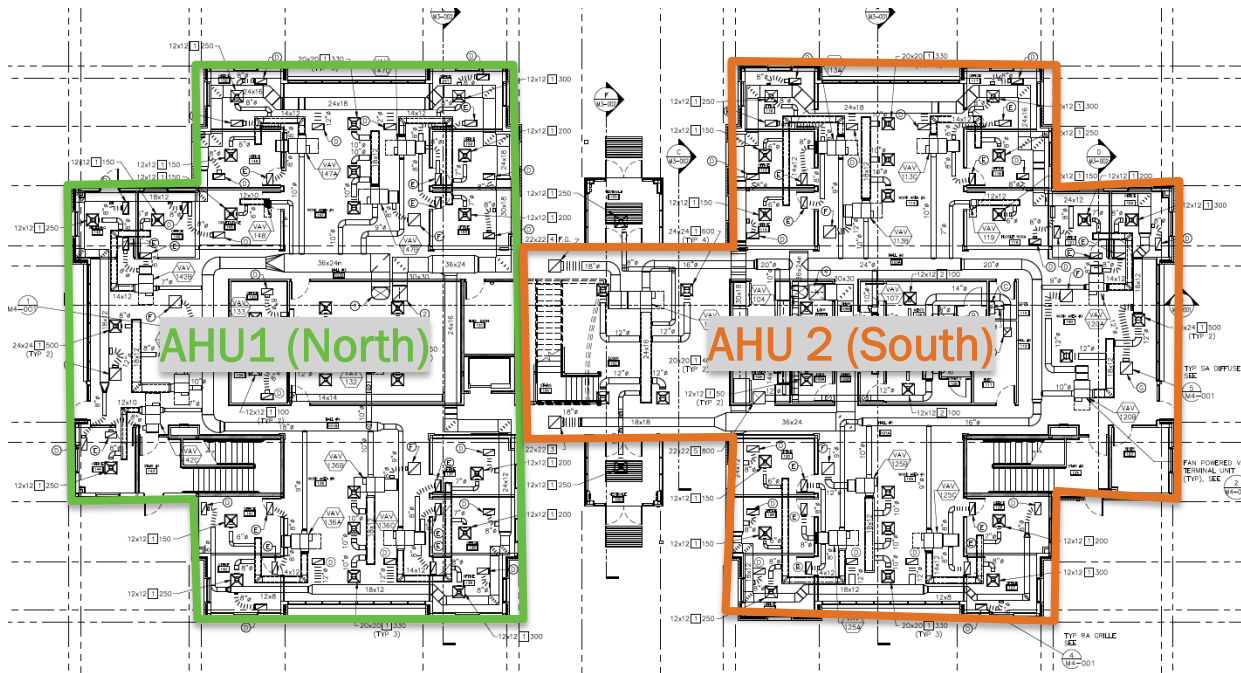
Selecting measurement locations

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 serves 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

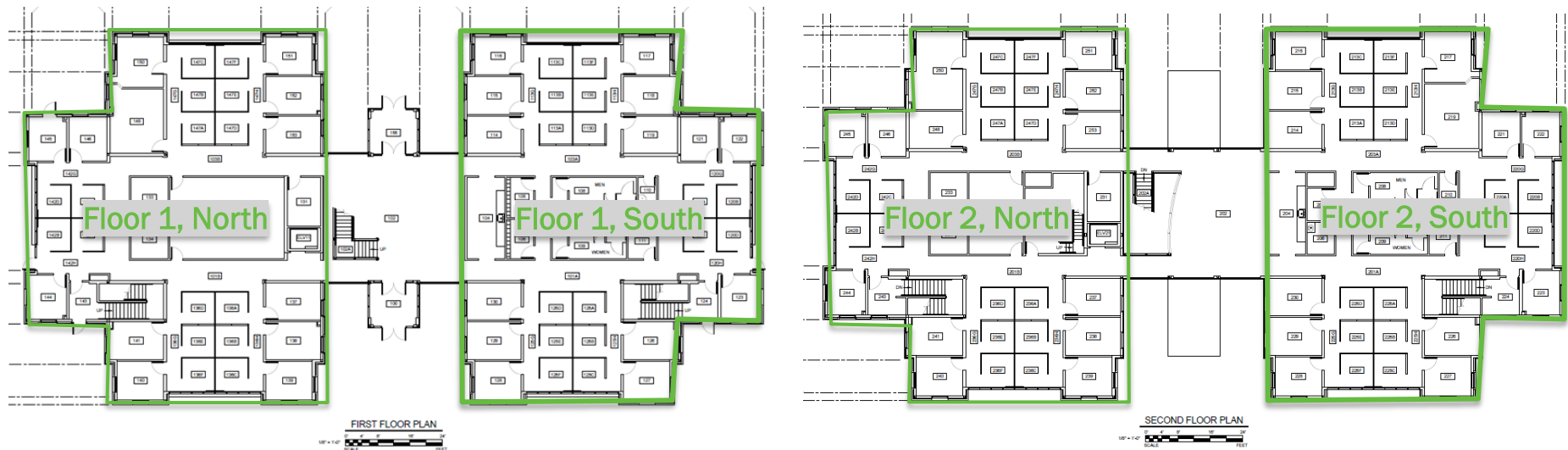
- This building has two floors, with the AHU zones traveling vertically through each floor. Each of the IAQ (e.g., Kaiterra sensedge) data loggers will be associated with one of the two AHUs for the air quality recommendations.
- Each IAQ data logger will also be assigned a more granular zone and the lighting (e.g., LICOR LI210R) will be assigned only a granular zone. See the following slides for an example on selecting these 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 recommend a minimum of 8 data logger locations per 50,000 sq.ft. This building comprises approximately 30,000 sq.ft. of floor area, so we will round up to 8 locations.
- We want between two and three locations per zone for the data loggers. That comes out to four zones.
- It is most convenient to use the same zones for both data loggers (IAQ and lighting), 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

- We will place two data loggers in each zone and look for a representation of Open Office, Enclosed Office, and Conference Rooms, as well as general geographic distribution.
 - Kitchens, bathrooms, hallways, and atriums are not areas where occupants need to be “productive” and therefore are not considered critical zones to measure.
- Below is an example of what a selection could look like.

