

HEALTHY  
PEOPLE



HEALTHY  
ENERGY

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# CO-OPTIMIZING INDOOR AIR QUALITY AND ENERGY USE IN CORPORATE OFFICES

AMANDA HERNANDEZ, MS  
DATA ANALYST



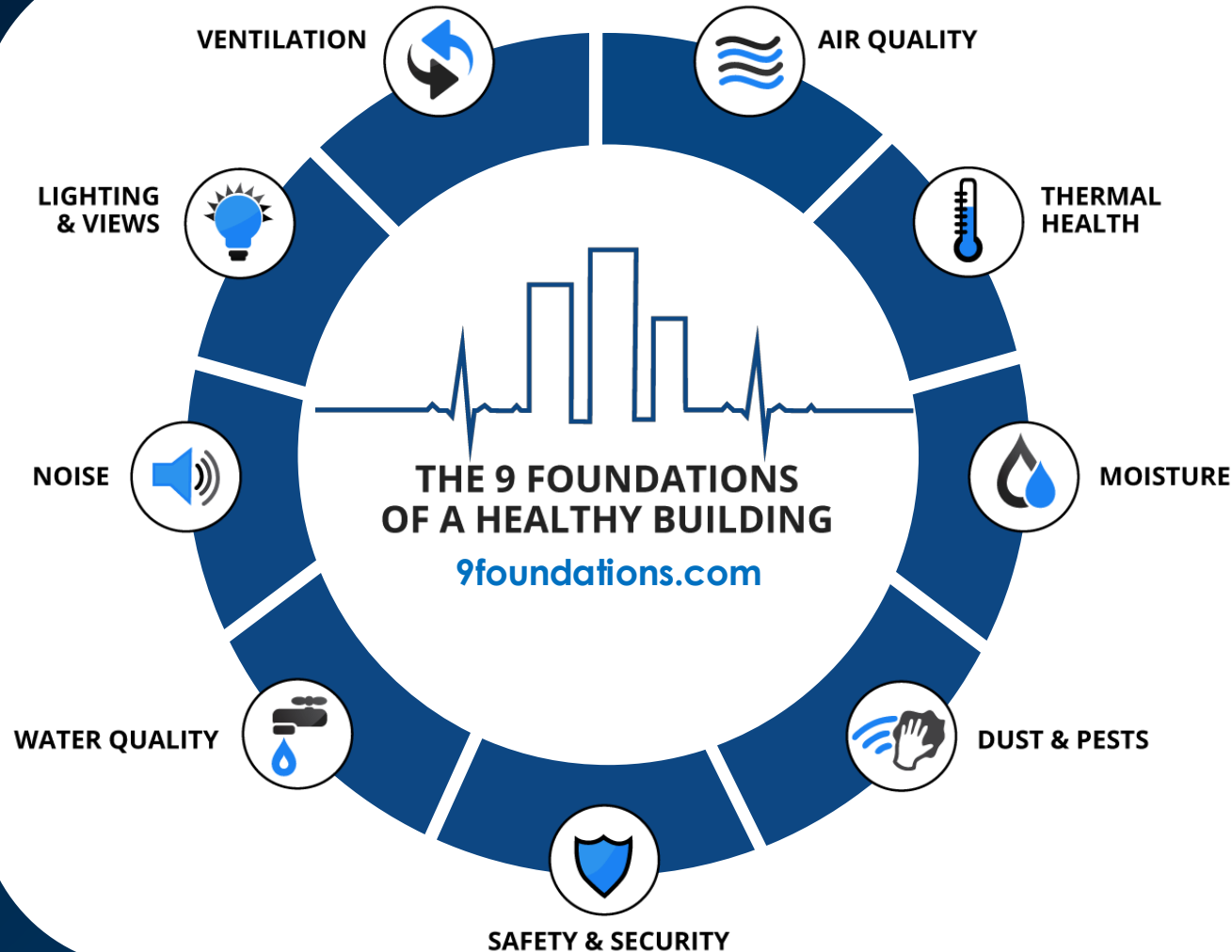
FOUNDATIONS

# INTRODUCTION

HEALTHY  
PEOPLE



HEALTHY  
ENERGY



## The 9 Foundations of a Healthy Building

were created by a multidisciplinary team of experts from the Healthy Buildings Program at Harvard T.H. Chan School of Public Health. The 9 Foundations are the core elements of healthy indoor environments, distilled into clear and actionable guidance, and designed to bridge the gap between scientific research and you – the people who control, manage and occupy buildings.

**Healthy Buildings.**  
**Built on Science.**

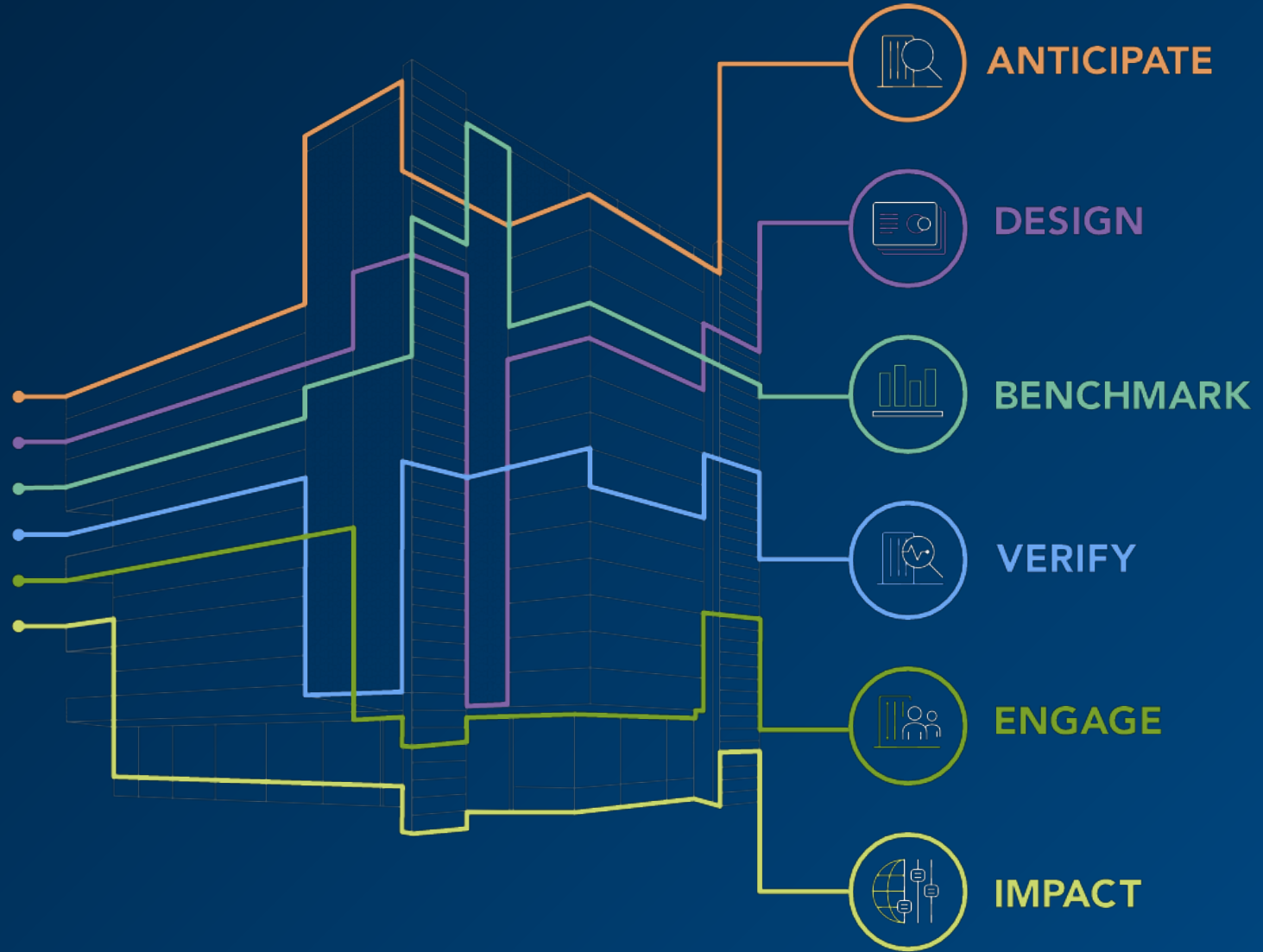
HEALTHY  
PEOPLE



HEALTHY  
ENERGY



HEALTHY  
BUILDINGS  
SOLUTIONS







## HEALTHY BUILDINGS

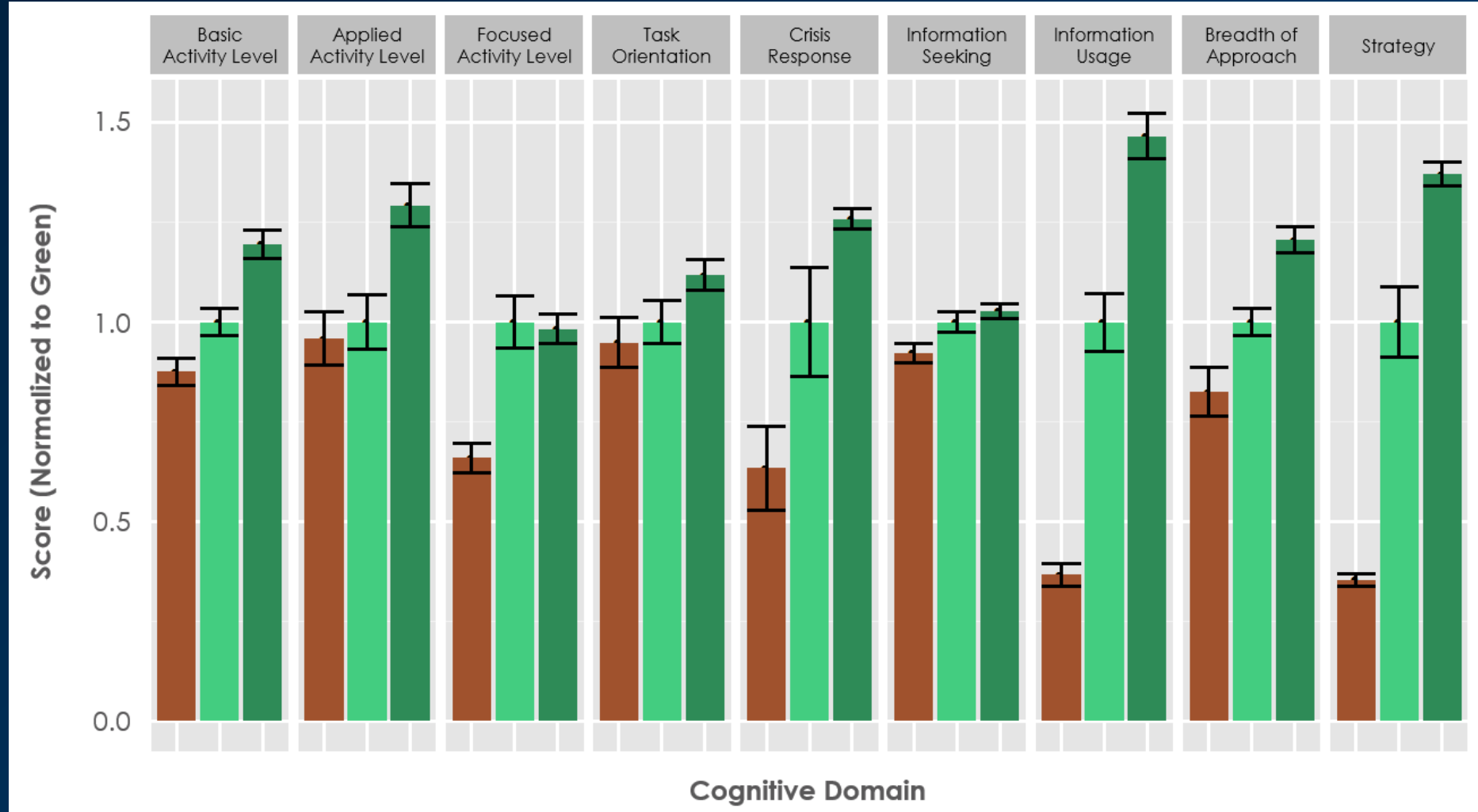


HEALTHY  
PEOPLE

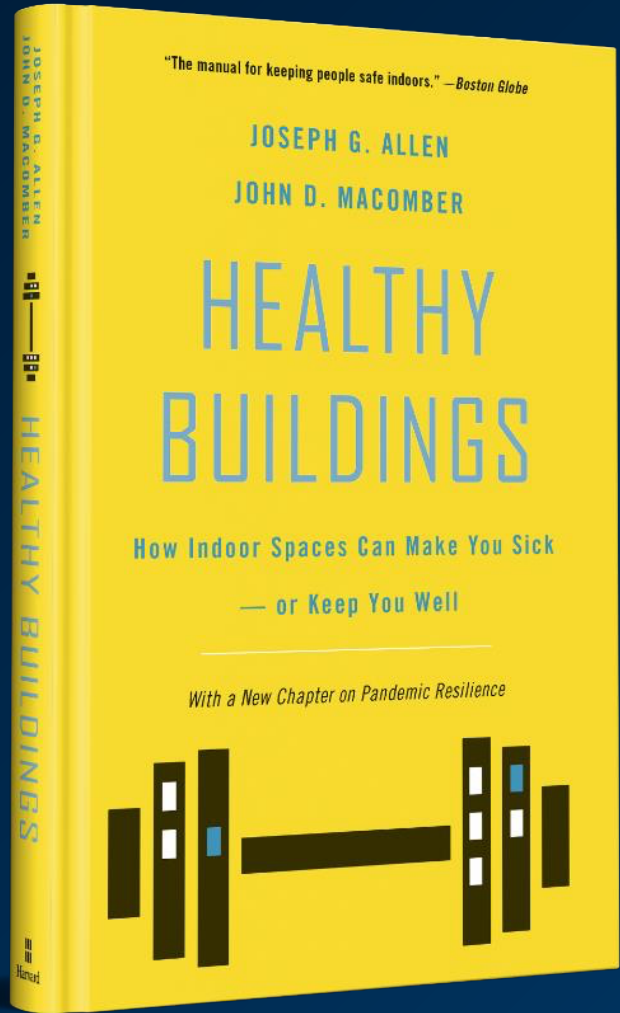


HEALTHY  
ENERGY





# THE BUSINESS CASE FOR HEALTHY BUILDINGS



## ENERGY SAVINGS

## ABSENTEEISM SAVINGS

## PRODUCTIVITY BOOST

## FULL PRODUCTIVITY AND HEALTH

### Itemized impacts of healthy building decisions

Baseline	OpExImpacts	Payroll Effect: Health	Productivity Boost: Health	Baseline + Healthy Buildings
Revenue	\$6,000,000		3% \$180,000	\$6,180,000
Payroll	(\$3,000,000)	-1% \$30,000		\$(2,970,000)
Rent	\$(300,000) 10% \$(30,000)			\$(330,000)
Utilities	\$(30,000) \$(1,600)			\$(31,600)
Other Expenses	\$(1,000,000)			\$(1,000,000)
Net income before taxes	\$1,670,000			\$1,848,400
Taxes (30%)	\$501,000			\$554,520
Net income after taxes	\$1,169,000			\$1,293,880

Changes:

10.7%

### Baseline Company Assumptions

Number of employees	40
Average salary	\$75,000
Payroll as % of revenue	50%



# NOW

NATIONAL OFFICE  
WORKER SURVEY

# Survey

# 2025





# Do office workers value health and safety?

National  Office Worker Survey

[www.9Foundations.com/NOWSurvey](https://www.9Foundations.com/NOWSurvey)

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# Health and safety are baseline expectations

Health and safety remain consistent priorities across U.S. office workers. In this nationally representative survey of 1,000 office workers, 93% said they want their workplaces to support their health and safety, regardless of age and role. These results indicate that healthy building conditions are now viewed as part of the basic employment standard – an expectation embedded in how workers define a good workplace, rather than an added benefit.

# 93%

of respondents said  
**they want their office  
to support their health  
and safety**

# Executives

Have questions

82%

said they frequently or occasionally have questions or concerns about the indoor air quality at their workplace

Want healthy workplaces

94%

said they would be more likely to choose a job with an office in a building that prioritizes good indoor air quality

Want informed property teams

100%

said it is important that their building owner or property management team is knowledgeable about health in the workplace environment



**Do healthy and sustainable buildings influence**  
how office workers view their employer, choose  
their job, and decide where to stay?

**National  Office Worker Survey**

[www.9Foundations.com/NOWSurvey](https://www.9Foundations.com/NOWSurvey)

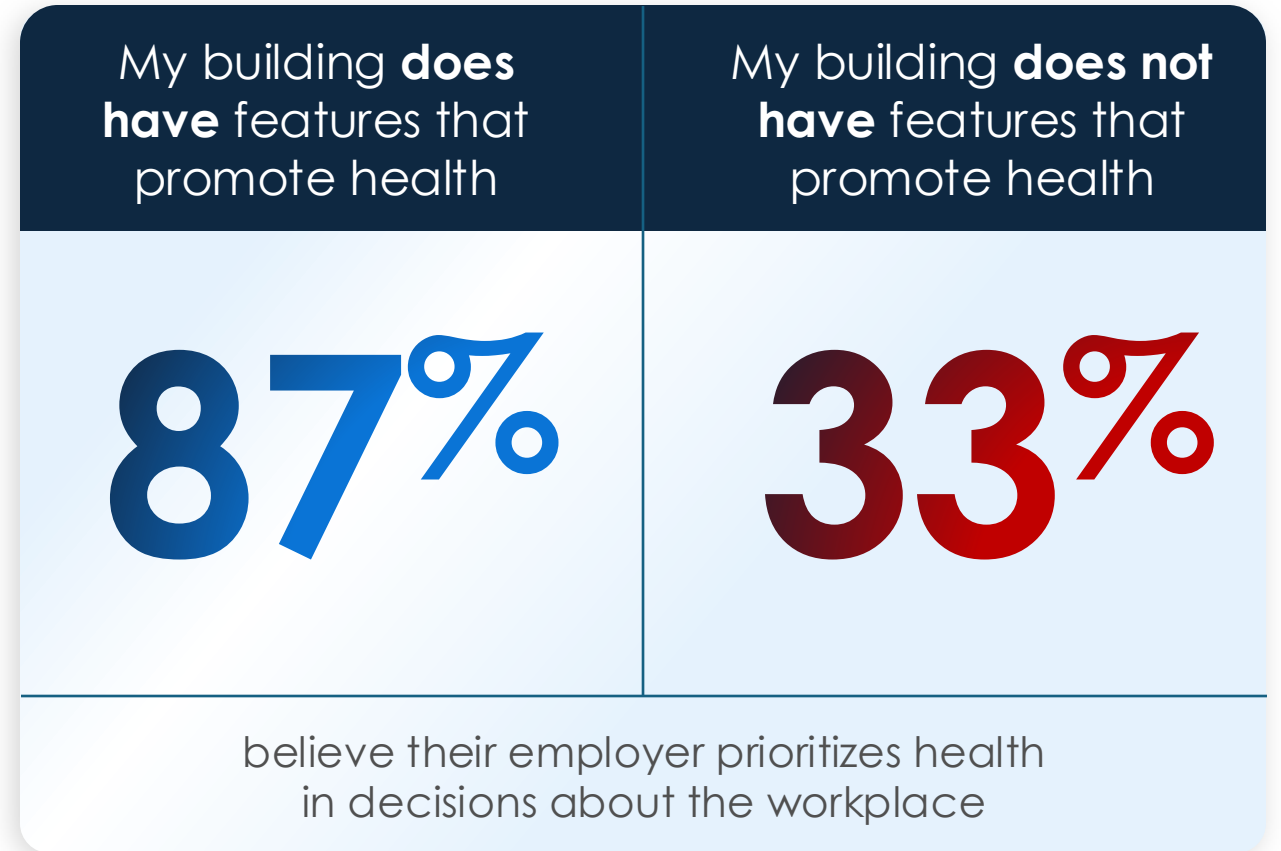
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## I believe my employer prioritizes health in decisions about the workplace.

Perceptions of employer commitment to health vary across workplace environments. Employees working in health-promoting buildings are nearly three times more likely to believe their employer prioritizes health (87% vs. 33%) – suggesting visible investments in healthy buildings shape how employees perceive organizational values and leadership priorities.





# Which healthy buildings foundations matter most to office workers?

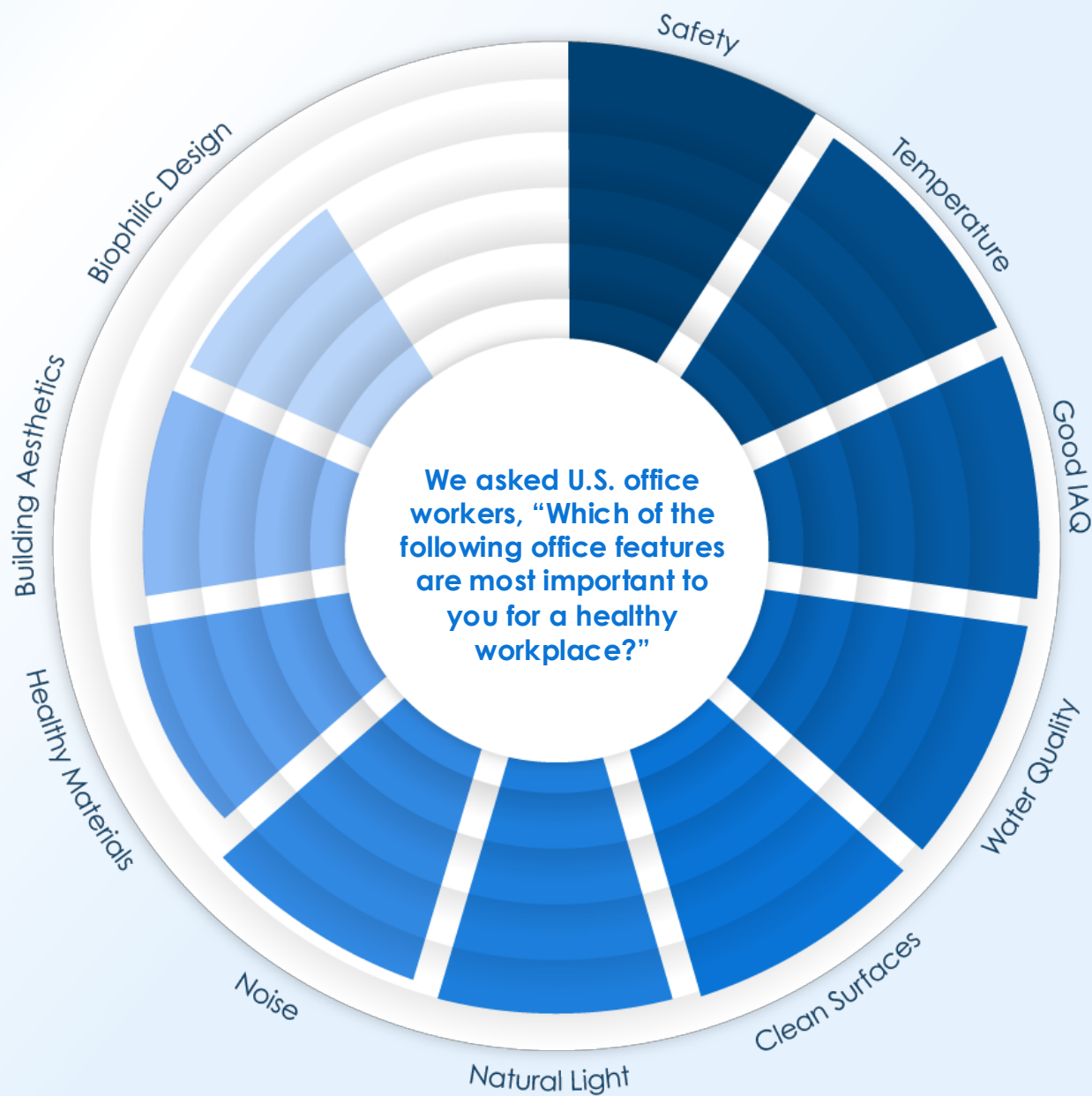
**National  Office Worker Survey**

[www.9Foundations.com/NOWSurvey](https://www.9Foundations.com/NOWSurvey)

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# Safety, Temperature, Indoor Air Quality, and Water Quality Matter Most.

Across all ages and roles, workers prioritized operational features – such as safety, comfortable temperatures, and good indoor air quality.



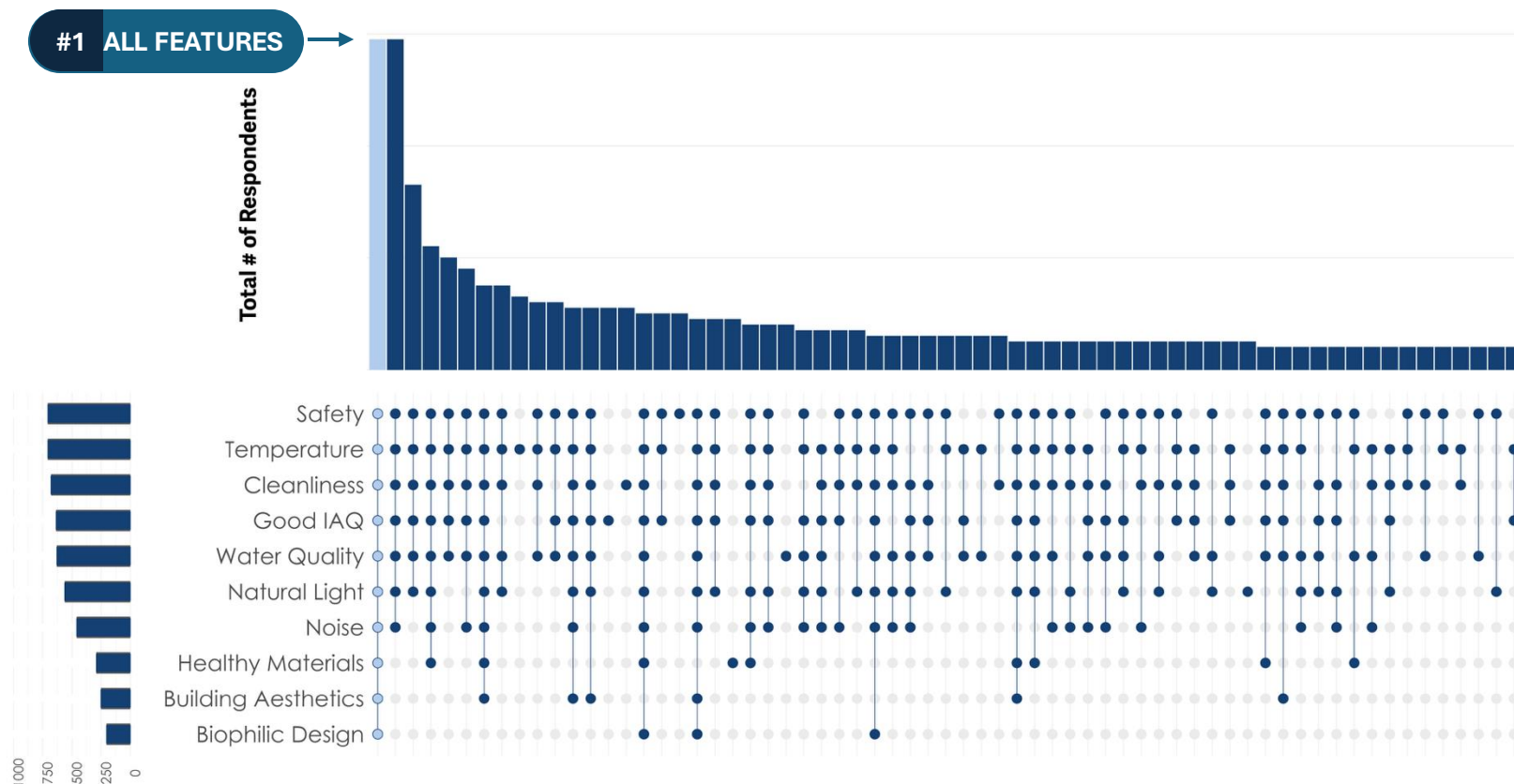
# Office workers want it all.

We asked U.S. office workers, “Which of the following office features are important to you in your workplace?”

The most common answer included all the features, followed by select combinations.



Which of the following office features are important to you in your workplace?



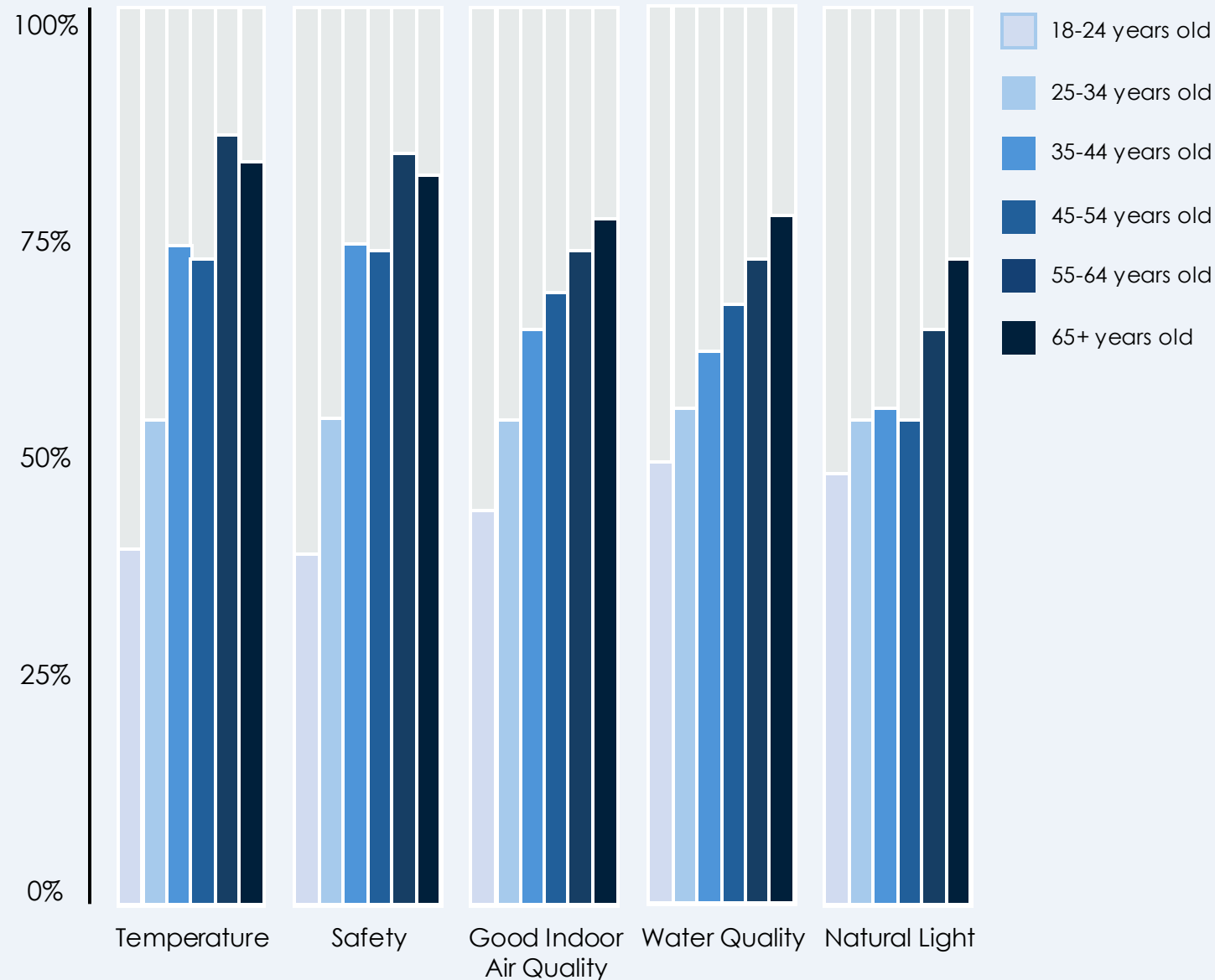
The largest percent increase in office workers who think safety, temperature, and indoor air quality are important occurs between workers ages 18-24 and 25-34.

**The newest workers quickly learn the value.**

The share of office workers who consider safety, temperature, indoor air quality, water quality, and natural light is highest among the oldest workers.

**And more seasoned workers know.**

Percentage of Respondents That Selected “Important”



# BUILDINGS SHAPE OUR WORLD – INSIDE AND OUT



## HEALTH

Indoor air quality is associated with acute symptoms, chronic conditions, & cognitive function



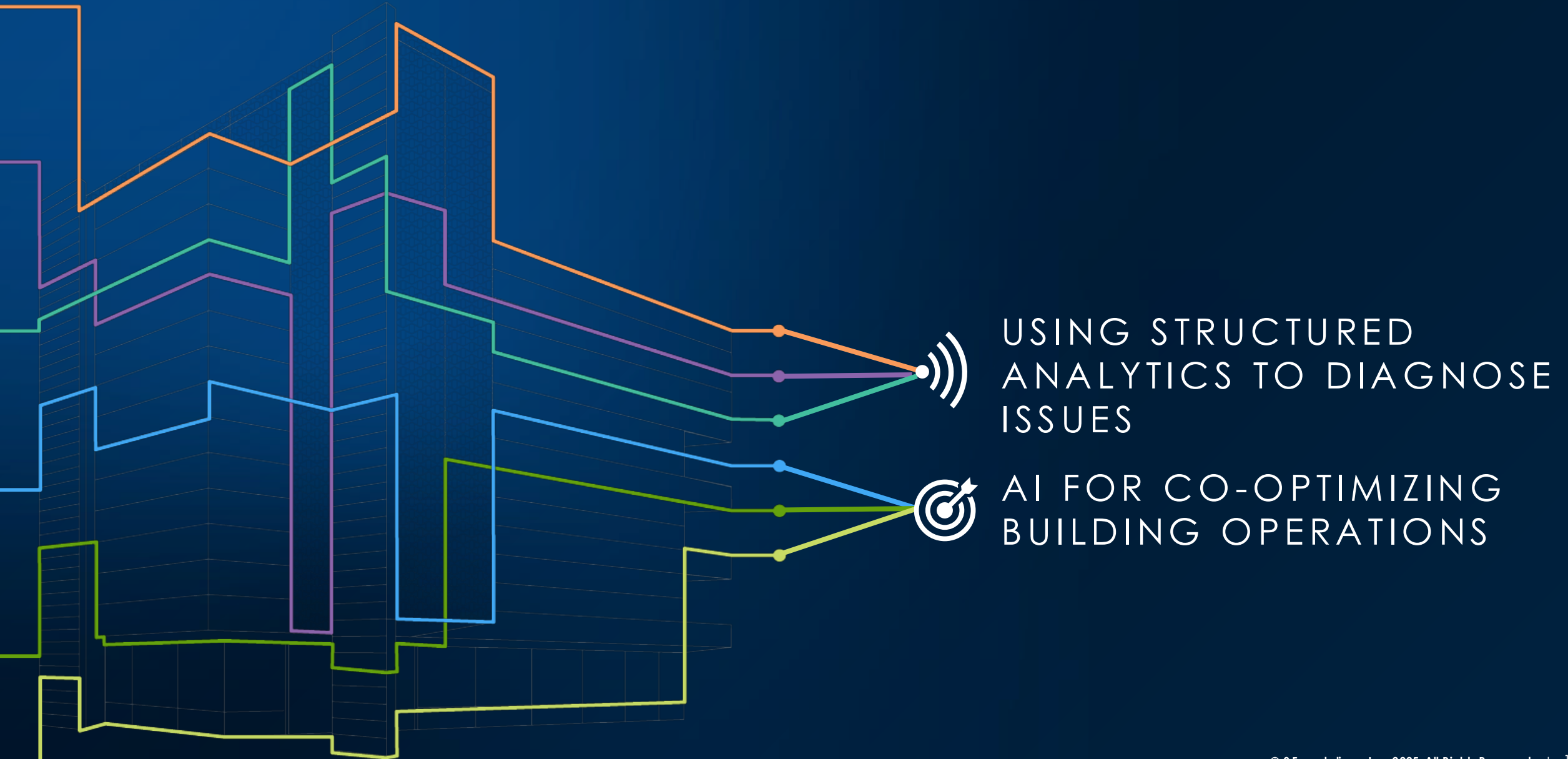
## SUSTAINABILITY

Buildings are responsible for more than 40% of global energy consumption & carbon emissions

## HEALTHY X SUSTAINABLE

The new equation for high performance buildings

# HEALTHY BUILDINGS MOVEMENT X SUSTAINABILITY





# USING STRUCTURED ANALYTICS TO DIAGNOSE ISSUES



HEALTHY  
PEOPLE



HEALTHY  
ENERGY

## DEPLOY

Low-cost IAQ sensors capture real-time indoor air quality (IAQ) data across buildings.

## ANALYZE

Data are collected, aggregated, and benchmarked against 9F's science-based H.E.A.A.L.® thresholds.

## ACT

Insights translate directly into actions that help teams maintain healthier, higher-performing buildings.



## OPTIMIZE HEALTH

H.E.A.A.L.® transforms real-time IAQ data into a measurable standard for health performance.

# HEALTHY PEOPLE



# HEALTHY ENERGY

Focus  
Stakeholders  
Solutions

## The Science

Legal,  
Risk Management

H.E.A.A.L. Thresholds					
		CO <sub>2</sub> (ppm)	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	TVOC (ppb)	Radon (pCi/l)
<b>H</b>	Health Optimized	<800	<5	<300	<0.4
<b>E</b>	Excellent	800 – 1000	5 – 15	300 – 1000	0.4 – 1.3
<b>A</b>	Action	1000 – 1500	15 – 35	1000 – 2000	1.3 – 2.0
<b>A</b>	Alert	1500 – 2500	35 – 50	2000 – 3000	2.0 – 4.0
<b>L</b>	Limit	≥2500	≥50	≥3000	≥4.0

## Real-time Performance

Facilities Managers



## Insights

Facilities Managers,  
EH&S, Executives



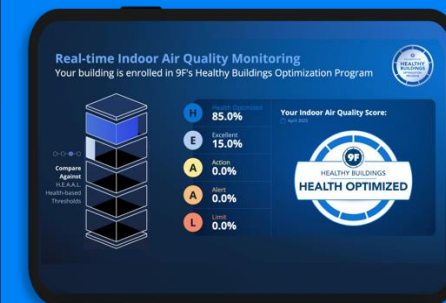
## Response

Facilities Managers,  
EH&S, Executives



## Communications

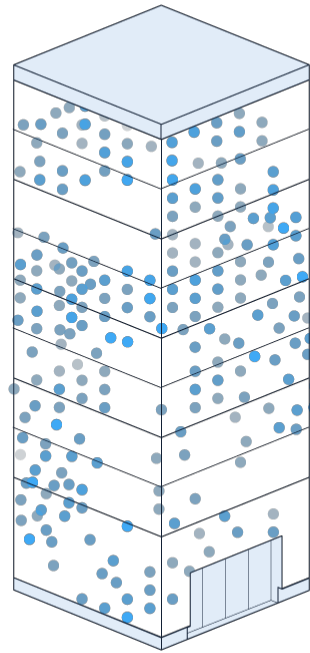
Employees and  
the Public



# HEALTHY PEOPLE

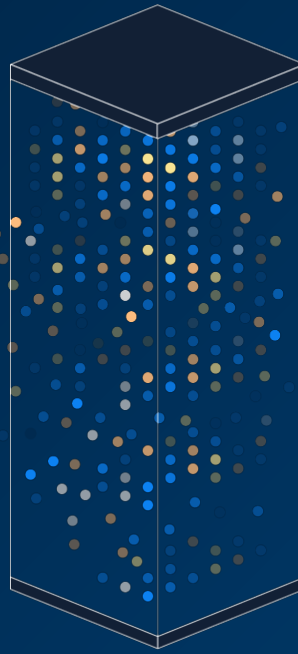


# HEALTHY ENERGY



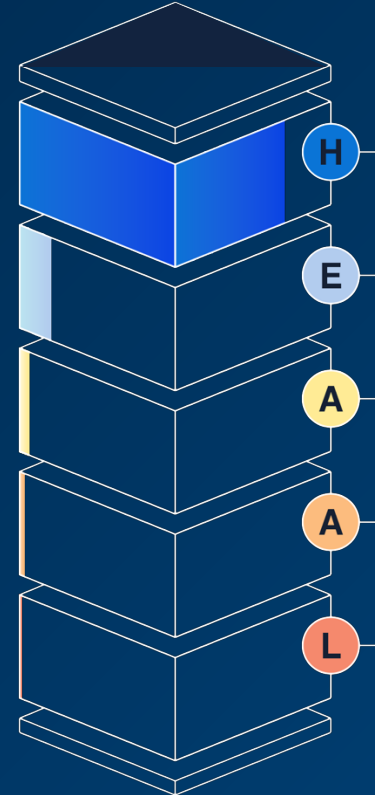
## Collect Raw Environmental Sensor Data

Raw indoor environmental quality data is collected by sensors in a building.



## Aggregate Raw Data

Raw data are aggregated into 1-hour averages covering the building's occupied hours.



## Compare against the H.E.A.A.L. Exposure Thresholds

Averages are compared against parameter-specific thresholds.



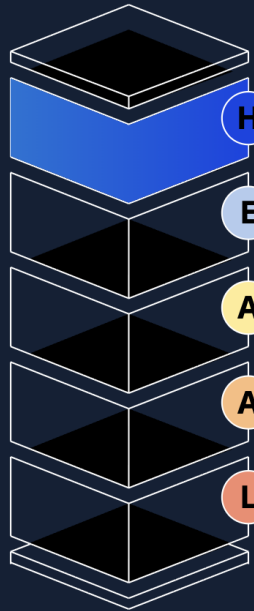
## Score the Building

The building's indoor air quality and thermal scores, as well as action, alert, and limit notifications, are based on how data compare to the parameter-specific thresholds.



# Health & IAQ :: Building 1

● Live data



H	Health Optimized	99.2%
E	Excellent	0.2%
A	Action	0.3%
A	Alert	0.3%
L	Limit	0.1%

CO<sub>2</sub>

413  
ppm

PM<sub>2.5</sub>

0  
μg/m<sup>3</sup>

TVOC

229  
ppb

CO<sub>2</sub>

PM<sub>2.5</sub>

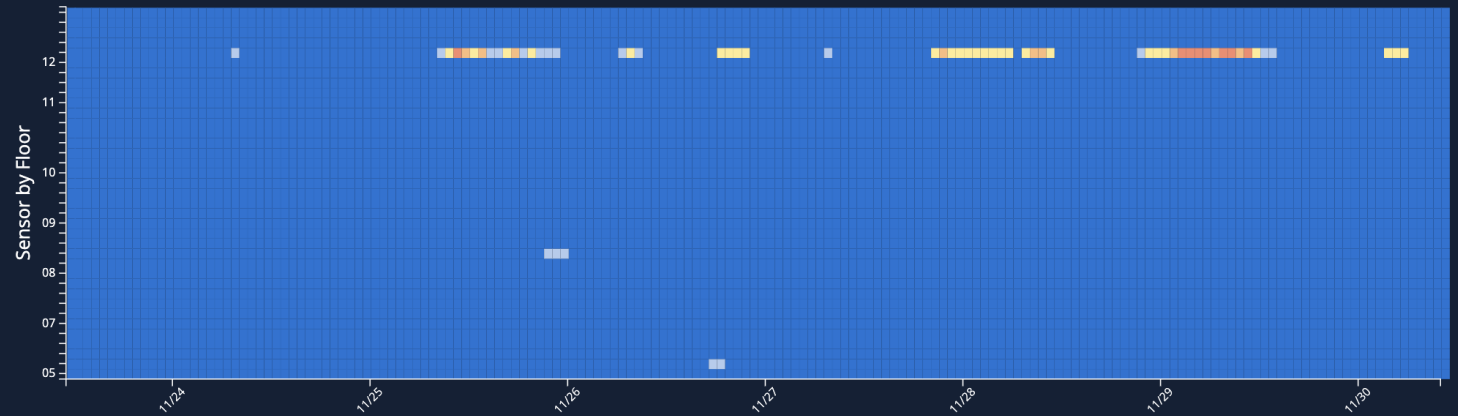
TVOC

30 Days

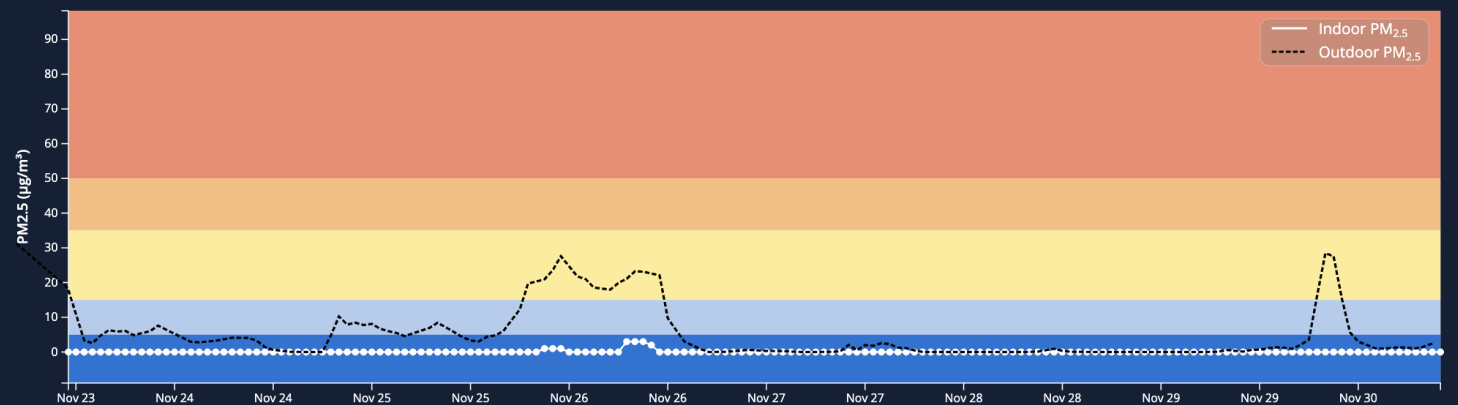
7 Days

BLDG1

H.E.A.A.L. PM<sub>2.5</sub> SpaceTime Map



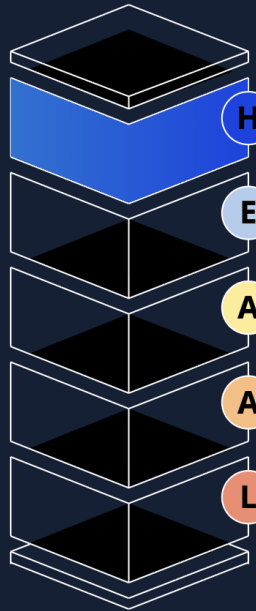
H.E.A.A.L. PM<sub>2.5</sub> Timeseries Plot





# Health & IAQ :: Building 1

● Live data



H	Health Optimized	99.2%
E	Excellent	0.2%
A	Action	0.3%
A	Alert	0.3%
L	Limit	0.1%

CO<sub>2</sub>

413  
ppm

PM<sub>2.5</sub>

0  
μg/m<sup>3</sup>

TVOC

229  
ppb

CO<sub>2</sub>

PM<sub>2.5</sub>

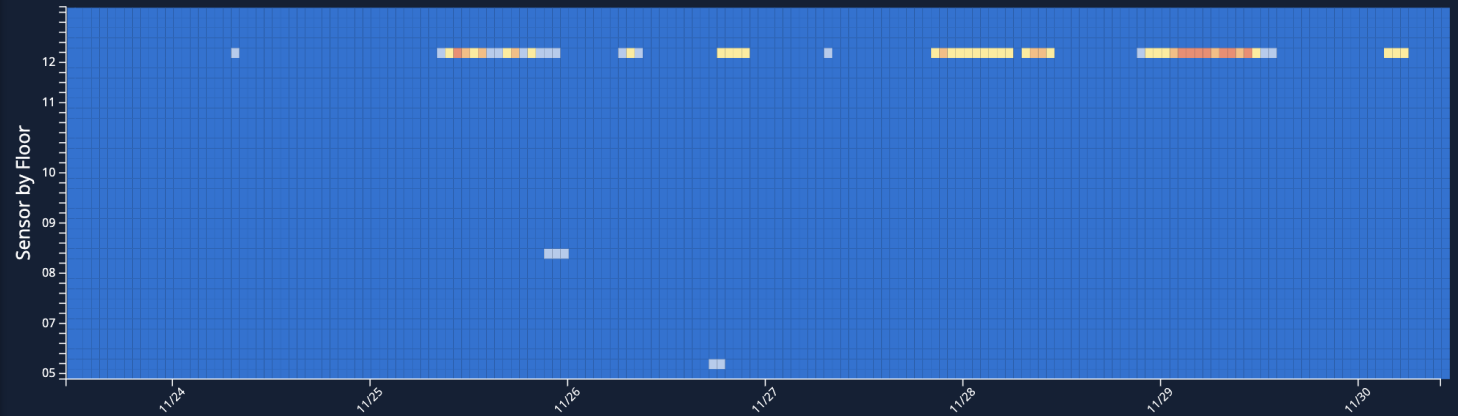
TVOC

30 Days

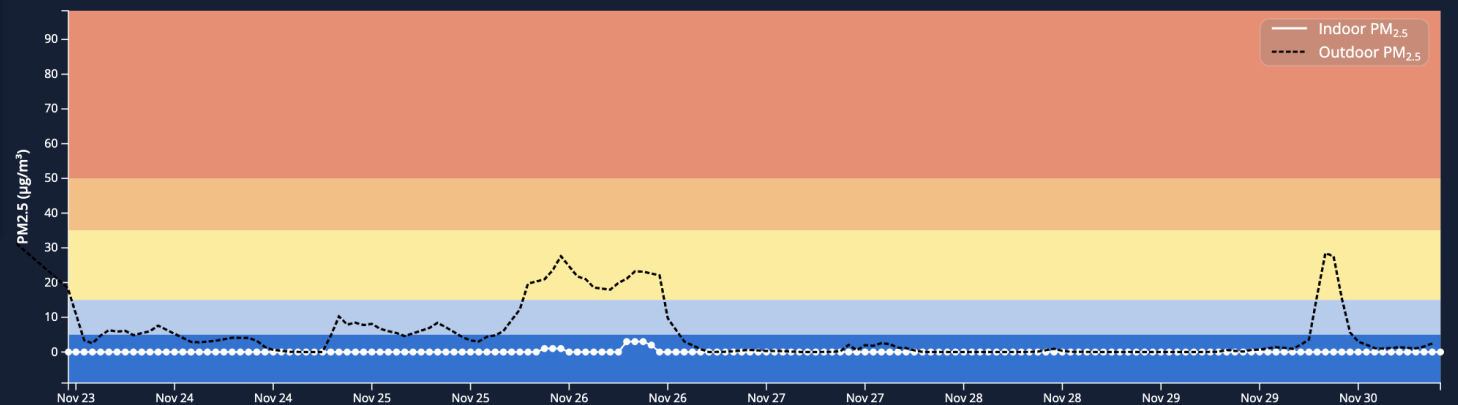
7 Days

BLDG1

H.E.A.A.L. PM<sub>2.5</sub> SpaceTime Map



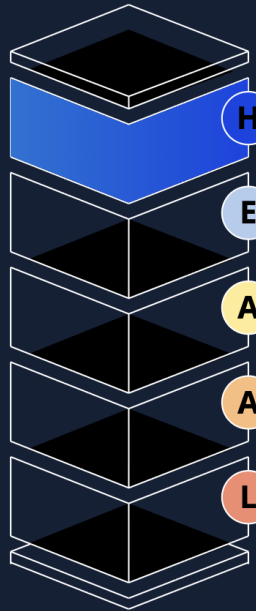
H.E.A.A.L. PM<sub>2.5</sub> Timeseries Plot





# Health & IAQ :: Building 1

● Live data



H	Health Optimized	99.2%
E	Excellent	0.2%
A	Action	0.3%
A	Alert	0.3%
L	Limit	0.1%

CO<sub>2</sub>

413  
ppm

PM<sub>2.5</sub>

0  
µg/m<sup>3</sup>

TVOC

229  
ppb

CO<sub>2</sub>

PM<sub>2.5</sub>

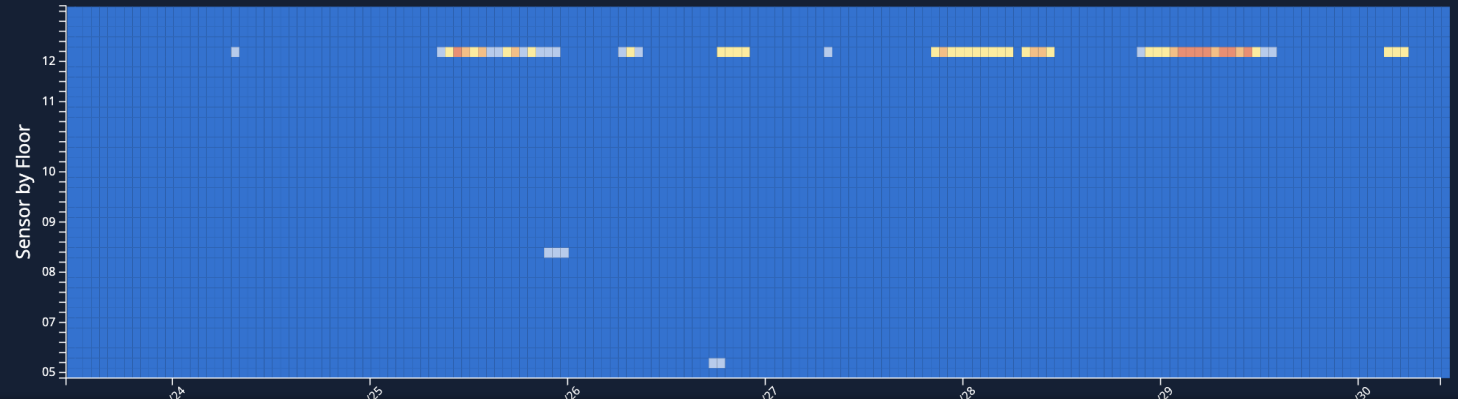
TVOC

30 Days

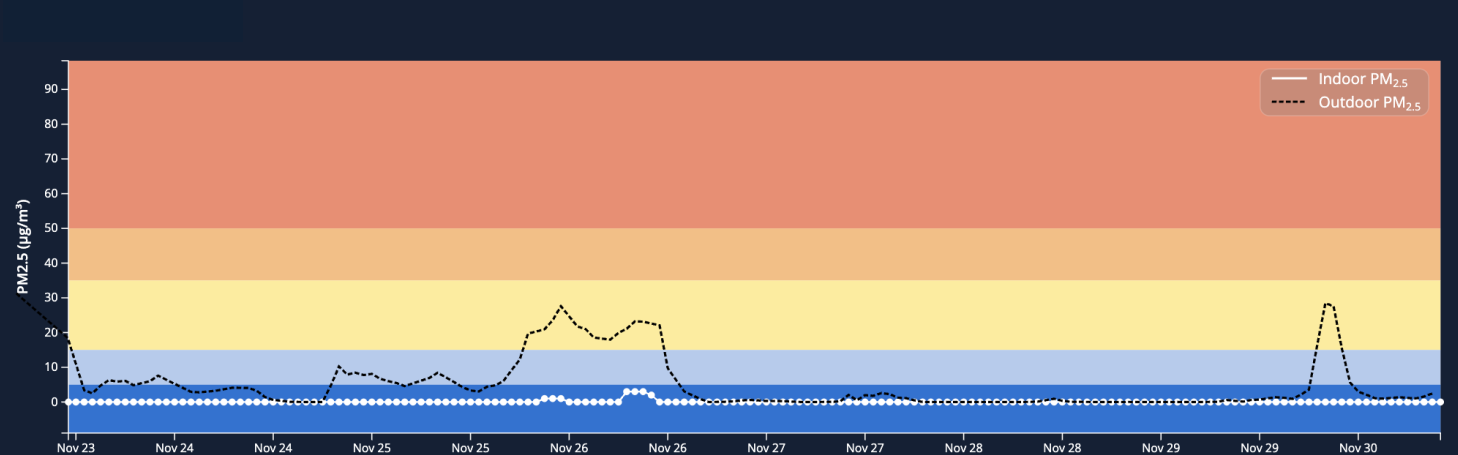
7 Days

BLDG1

H.E.A.A.L. PM<sub>2.5</sub> SpaceTime Map



H.E.A.A.L. PM<sub>2.5</sub> Timeseries Plot

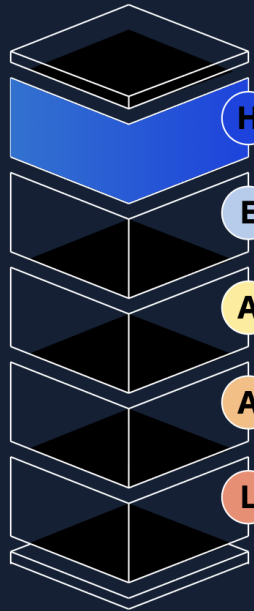






# Health & IAQ :: Building 1

● Live data



H	Health Optimized	99.2%
E	Excellent	0.2%
A	Action	0.3%
A	Alert	0.3%
L	Limit	0.1%

CO<sub>2</sub>

413  
ppm

PM<sub>2.5</sub>

0  
µg/m<sup>3</sup>

TVOC

229  
ppb

CO<sub>2</sub>

PM<sub>2.5</sub>

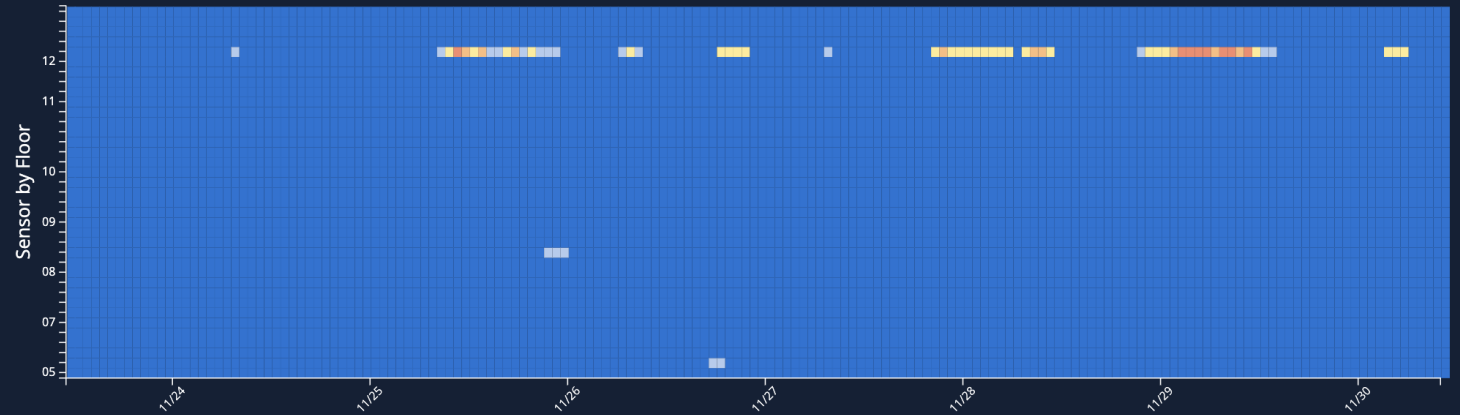
TVOC

30 Days

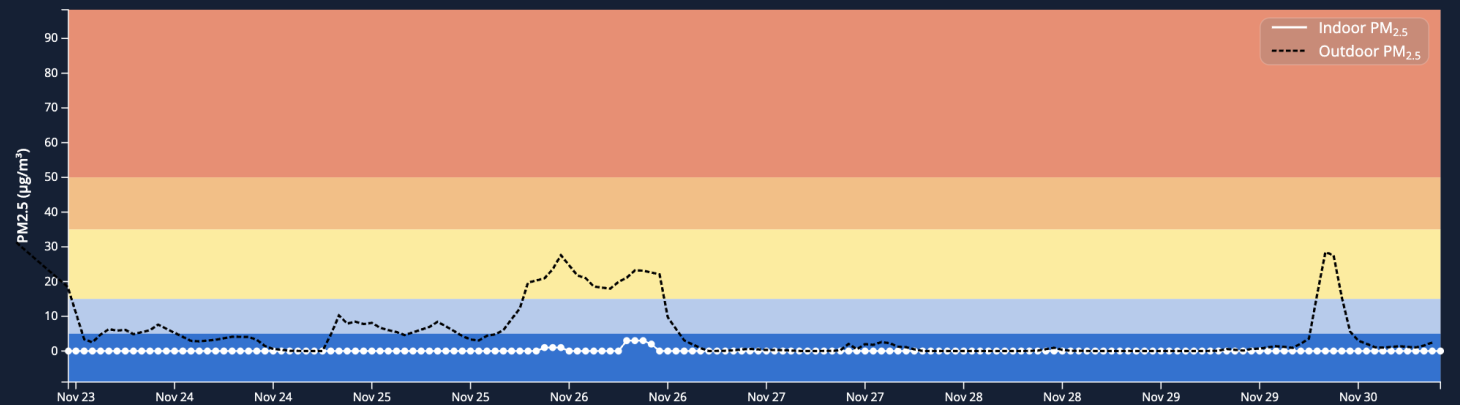
7 Days

BLDG1

H.E.A.A.L. PM<sub>2.5</sub> SpaceTime Map



H.E.A.A.L. PM<sub>2.5</sub> Timeseries Plot





High levels of outdoor PM<sub>2.5</sub>, such as during a wildfire event, can lead to elevated PM<sub>2.5</sub> indoors.



# Health & IAQ :: Building 1

● Live data



H	Health Optimized	5.1%
E	Excellent	21.6%
A	Action	14.9%
A	Alert	12.3%
L	Limit	46.1%

CO<sub>2</sub>

650 ppm

PM<sub>2.5</sub>

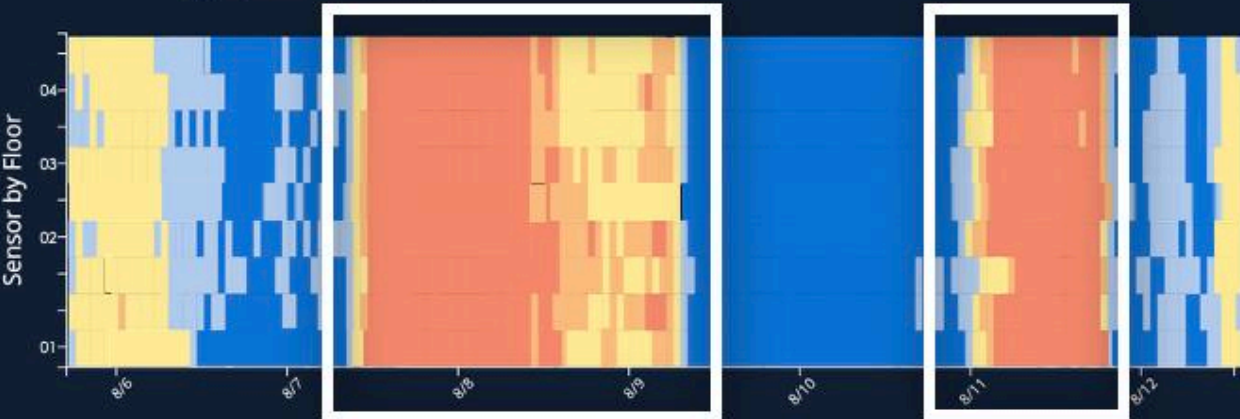
14 µg/m<sup>3</sup>

TVOC

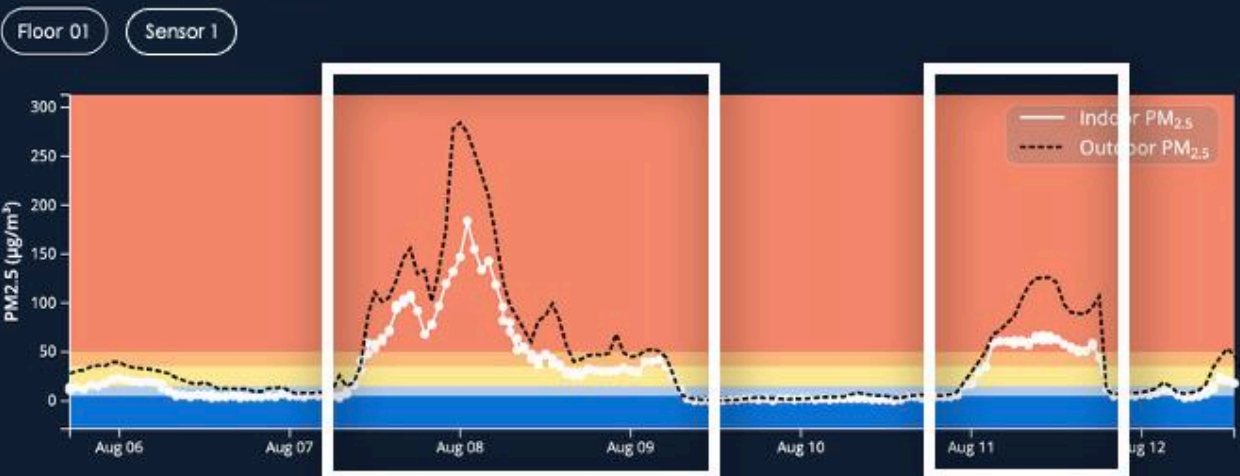
223 ppb

- CO<sub>2</sub>
- PM<sub>2.5</sub>**
- TVOC
- 30 Days
- 7 Days
- BLDG1**

H.E.A.A.L. PM<sub>2.5</sub> SpaceTime Map



H.E.A.A.L. PM<sub>2.5</sub> Timeseries Plot





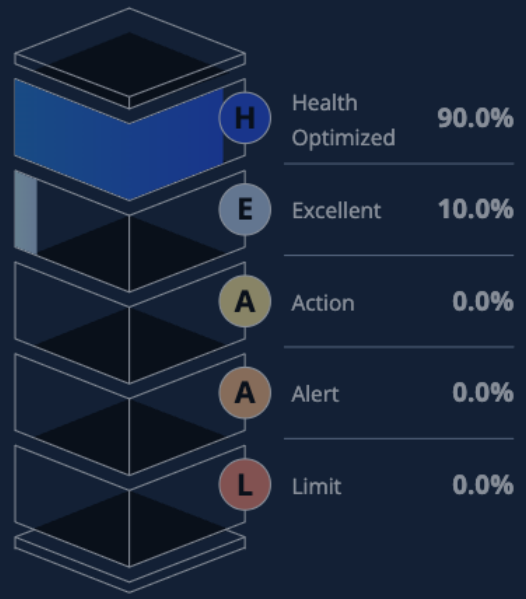


With proper filtration, indoor  $PM_{2.5}$  remains low indoors, even when outdoor  $PM_{2.5}$  is elevated.



# Health & IAQ :: Building 1

● Live data



CO<sub>2</sub>

453 ppm

PM<sub>2.5</sub>

4 µg/m<sup>3</sup>

TVOC

164 ppb

CO<sub>2</sub>

PM<sub>2.5</sub>

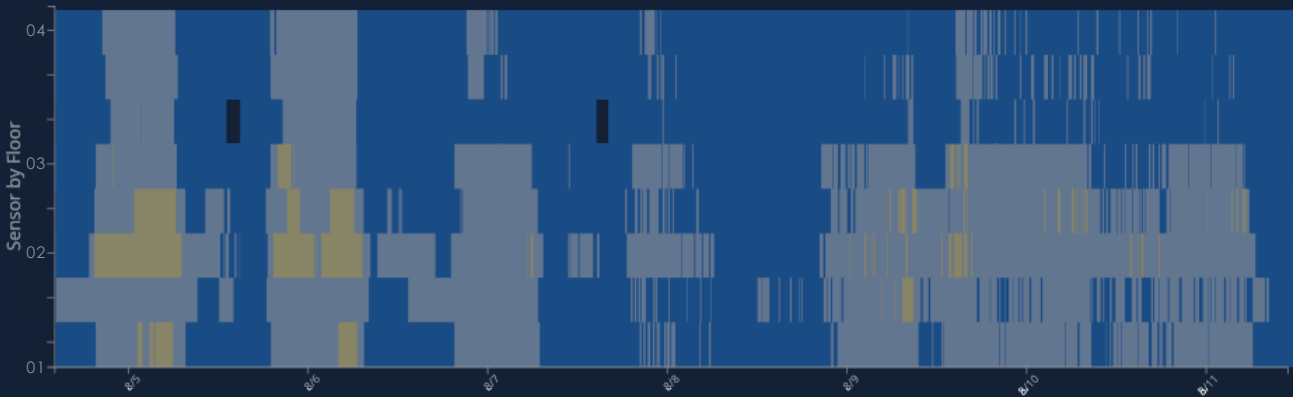
TVOC

30 Days

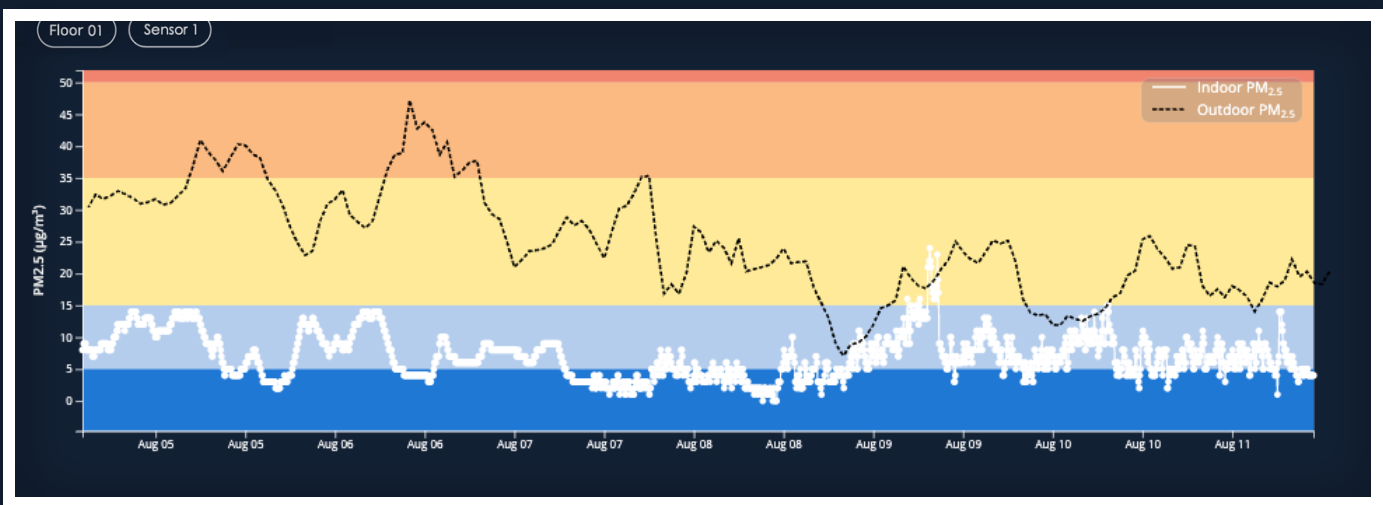
7 Days

BLDG1

H.E.A.A.L. PM<sub>2.5</sub> SpaceTime Map



H.E.A.A.L. PM<sub>2.5</sub> Timeseries Plot



9F's **OpRes Map** co-locates each building's performance against real-time or future outdoor conditions—helping teams visualize portfolio-wide comfort risks, prioritize buildings under the greatest strain, and deploy resources efficiently.

**Filters**

**Layer**  
Outdoor PM<sub>2.5</sub> ▼

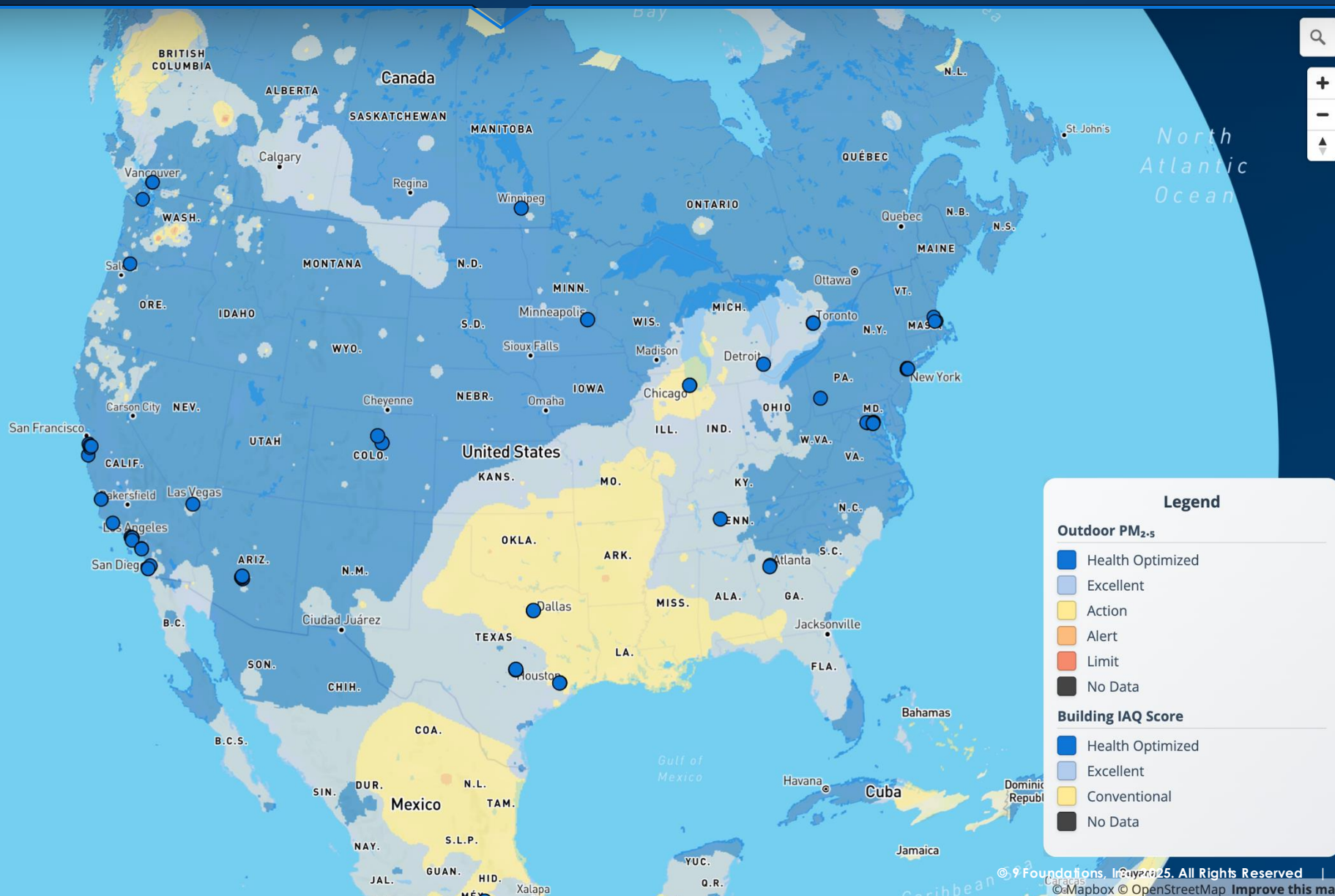
**Type**  
All ▼

**Building**  
Select... ▼

Reset Filters Reset Zoom

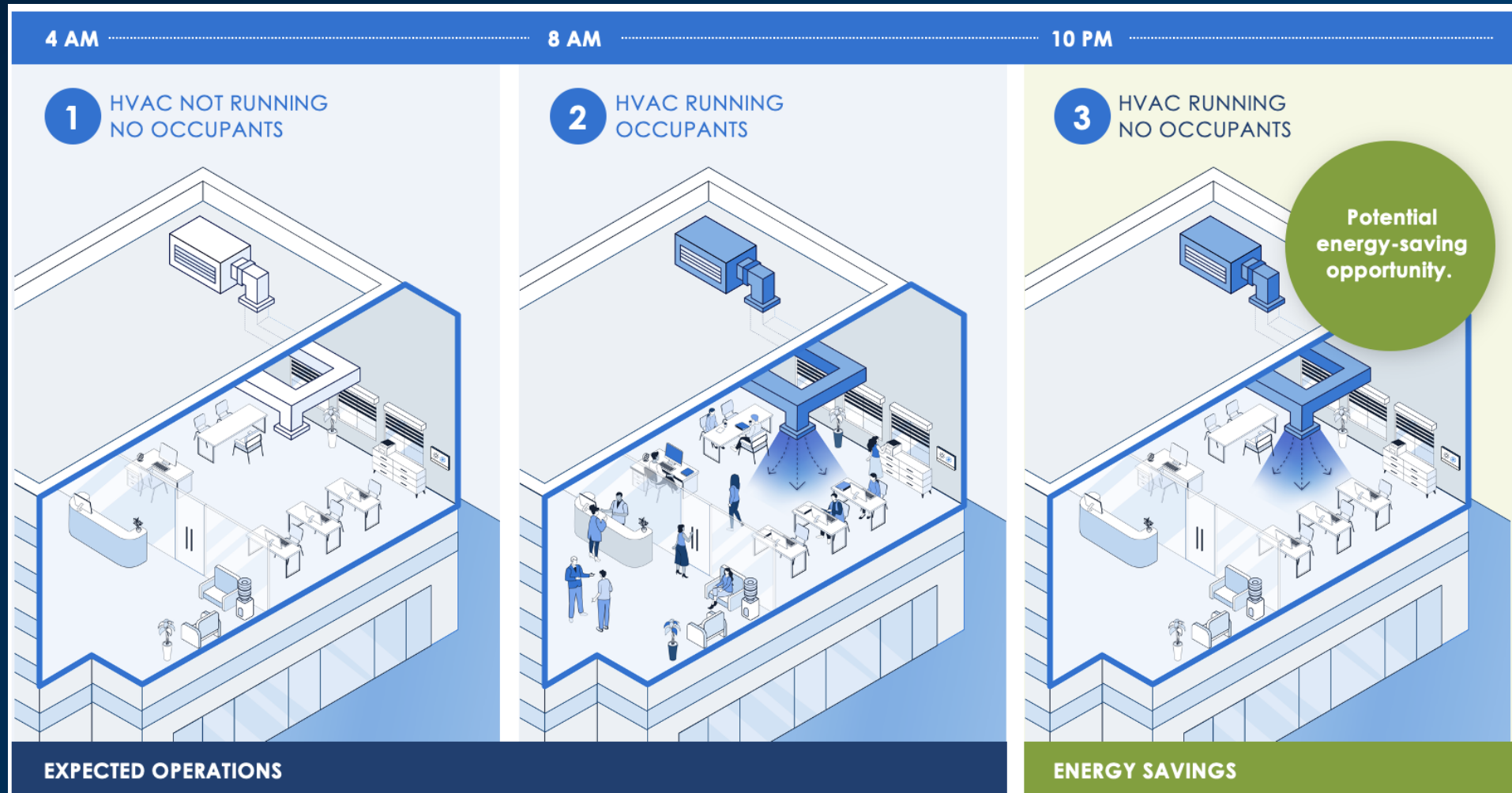
Download Filtered Data

Download Disclaimer Info





# AI FOR CO-OPTIMIZING BUILDING OPERATIONS







HEALTHY  
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HEALTHY  
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## DEPLOY

Low-cost IAQ sensors capture real-time indoor air quality (IAQ) data across buildings.

## LEARN

Data are run through Align's ML engine, enabling it to learn each building's unique operational and occupancy patterns.

## ACT

Automated insights reveal opportunities to reduce energy use while maintaining healthy IAQ.



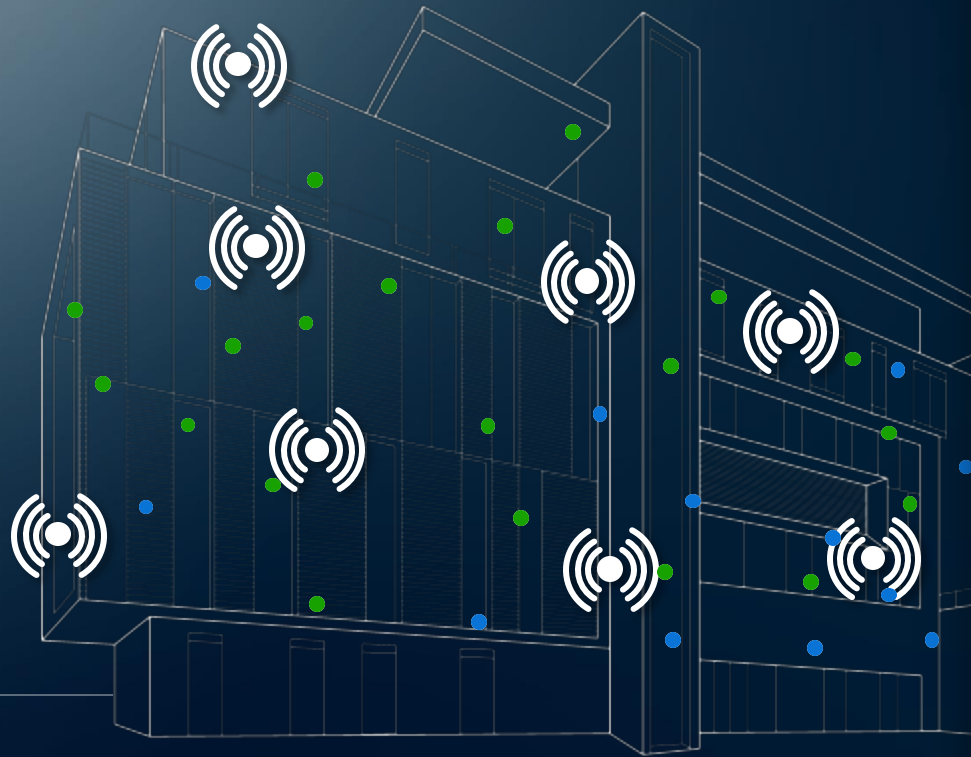
## PINPOINT OPPORTUNITIES

Align transforms real-time building data into actionable intelligence that improves energy efficiency while maintaining healthy, comfortable indoor environments.

# HEALTHY PEOPLE



# HEALTHY ENERGY



## FEATURE ENGINEERING

- Temporal dynamics
- Statistical features
- Calculus metrics

## WEEKLY SCHEDULE DETECTION

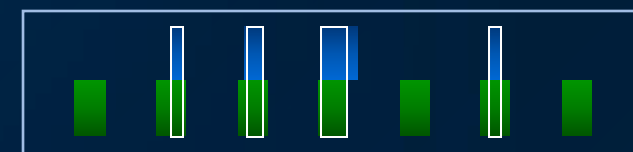
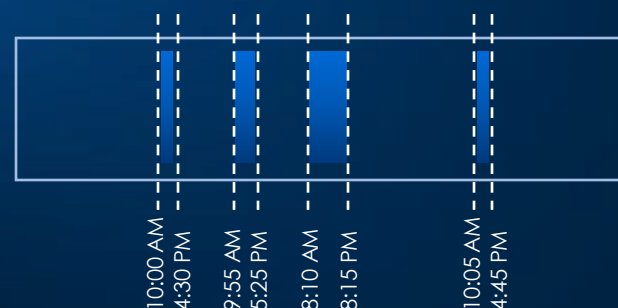
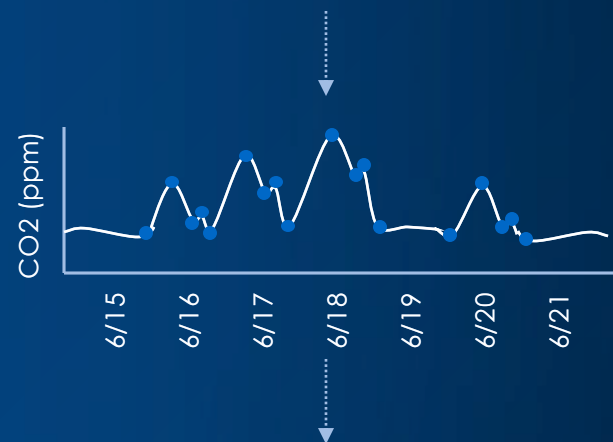
- Dynamic statistical algorithm
- Unsupervised machine learning model

## DAILY SCHEDULE DETECTION

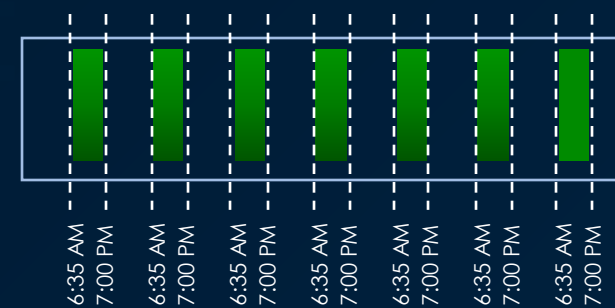
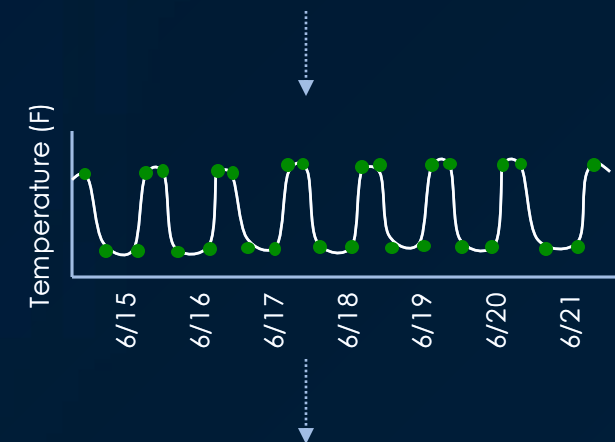
- Multi-level unsupervised machine learning models

## CO-OPTIMIZATION SCORING

### OCCUPANCY



### OPERATIONS



Operating Occupied Co-Optimized



Time periods when operations are well-aligned with occupancy — a sign of effective co-optimization for energy and health.



Time periods when operations is out of sync with occupancy — highlighting opportunities for energy savings and health benefits.



We partnered with  
a company to pilot Align™,  
and uncovered key insights across  
their U.S. building portfolio:

For 30,032 hours  
– **equivalent to 3.5 years** –  
buildings were occupied  
while they were not operating

For 175,560 hours  
– **equivalent to 20 years** –  
buildings were operating  
while they were not occupied

**Align™** can pinpoint  
portfolio-wide opportunities  
where buildings can save energy  
without compromising health

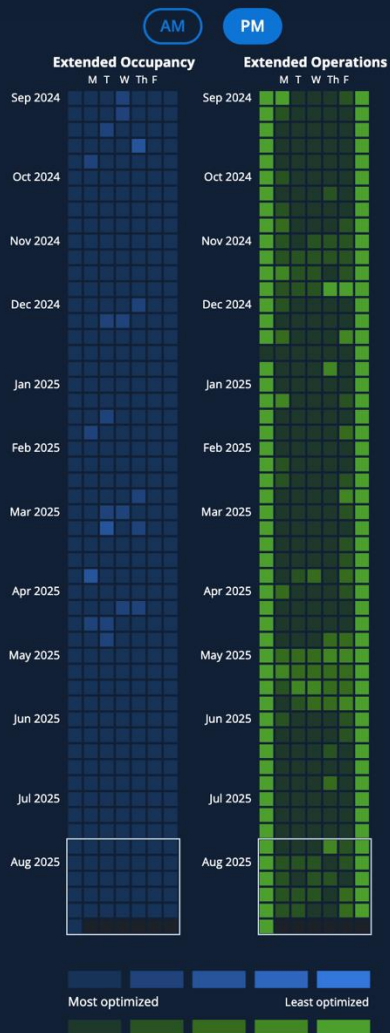




9F's AI-enabled **Align** engine automatically learns each building's operating and occupancy patterns—revealing opportunities to enhance energy efficiency while maintaining optimal occupant comfort.

## Align :: Building Insights

BLDGID



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## INGEST

Building characteristics and outputs from H.E.A.A.L. and Align are integrated into EnergyPlus.

## SIMULATE

Thousands of rapid, realistic scenarios runs are run through WEMBY's physics-based engine.

## RECOMMEND

Insights identify the most effective, strategies for improving building performance from an energy, health, and cost perspective.



## QUANTIFY SAVINGS

WEMBY creates “digital sisters” of buildings to rapidly simulate and optimize performance, revealing how implementing building interventions impact energy, health, and costs.

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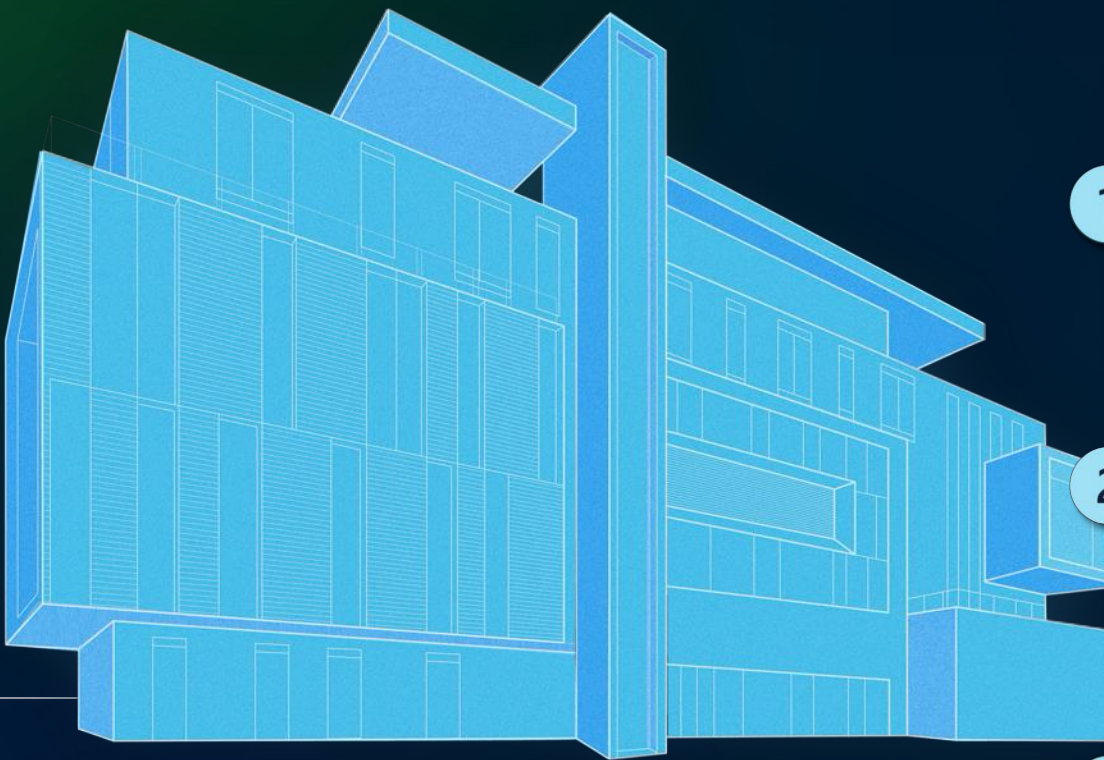


HEALTHY  
ENERGY

BUILDING

DIGITAL SISTER

SIMULATION



		ENERGY	DOLLARS	CARBON
1	ADJUST VENTILATION RATES	4.0% energy saved	\$5.6K costs saved	18 t CO <sub>2</sub> avoided
2	ADJUST WEEKEND SETBACK	2.3% energy saved	\$3.5K costs saved	8 t CO <sub>2</sub> avoided
3	ADJUST VENTILATION RATES + WEEKEND SETBACK	6.1% energy saved	\$8.4K costs saved	26 t CO <sub>2</sub> avoided



WEMBY



“DIGITAL SISTER”

	SCENARIO	ENERGY	DOLLARS	CARBON
1	ADJUST VENTILATION RATES	4.0% energy saved	\$5.6K costs saved	18 † CO <sub>2</sub> avoided
2	ADJUST WEEKEND SETBACK	2.3% energy saved	\$3.5K costs saved	8 † CO <sub>2</sub> avoided
3	ADJUST VENTILATION RATES + WEEKEND SETBACK	6.1% energy saved	\$8.4K costs saved	26 † CO <sub>2</sub> avoided





“DIGITAL SISTER”

1

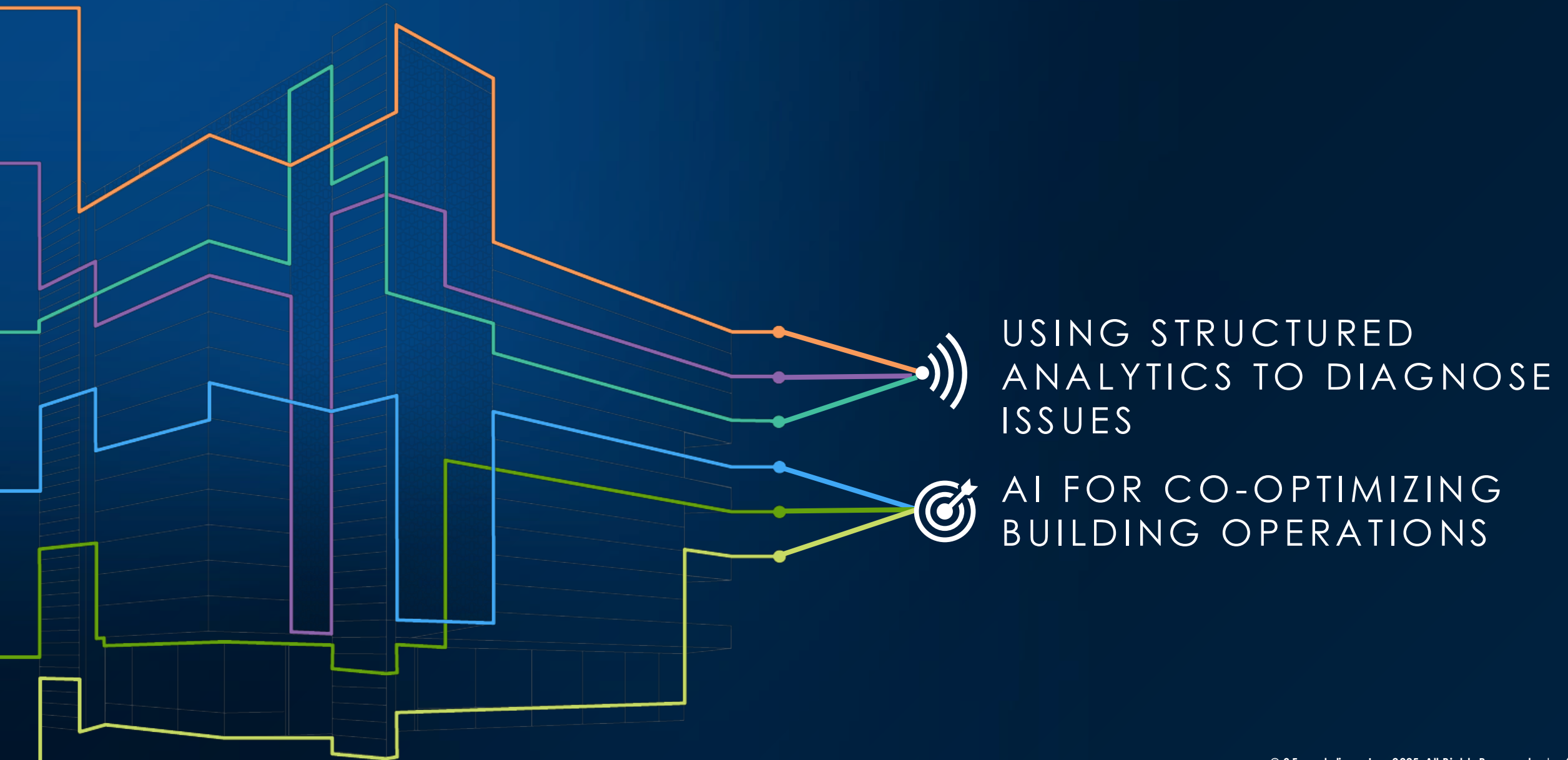
SCENARIO	ENERGY	DOLLARS	CARBON
ADJUST WEEKEND SETBACK	12.5% energy saved	\$3.0K costs saved	3.5 t CO <sub>2</sub> avoided



# CONCLUSIONS



# HEALTHY BUILDINGS MOVEMENT X SUSTAINABILITY





Uncompromising on the science.



Delivering excellence for our clients.

