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Balancing Data Collection Burden and Comprehensive IEQ Evaluation

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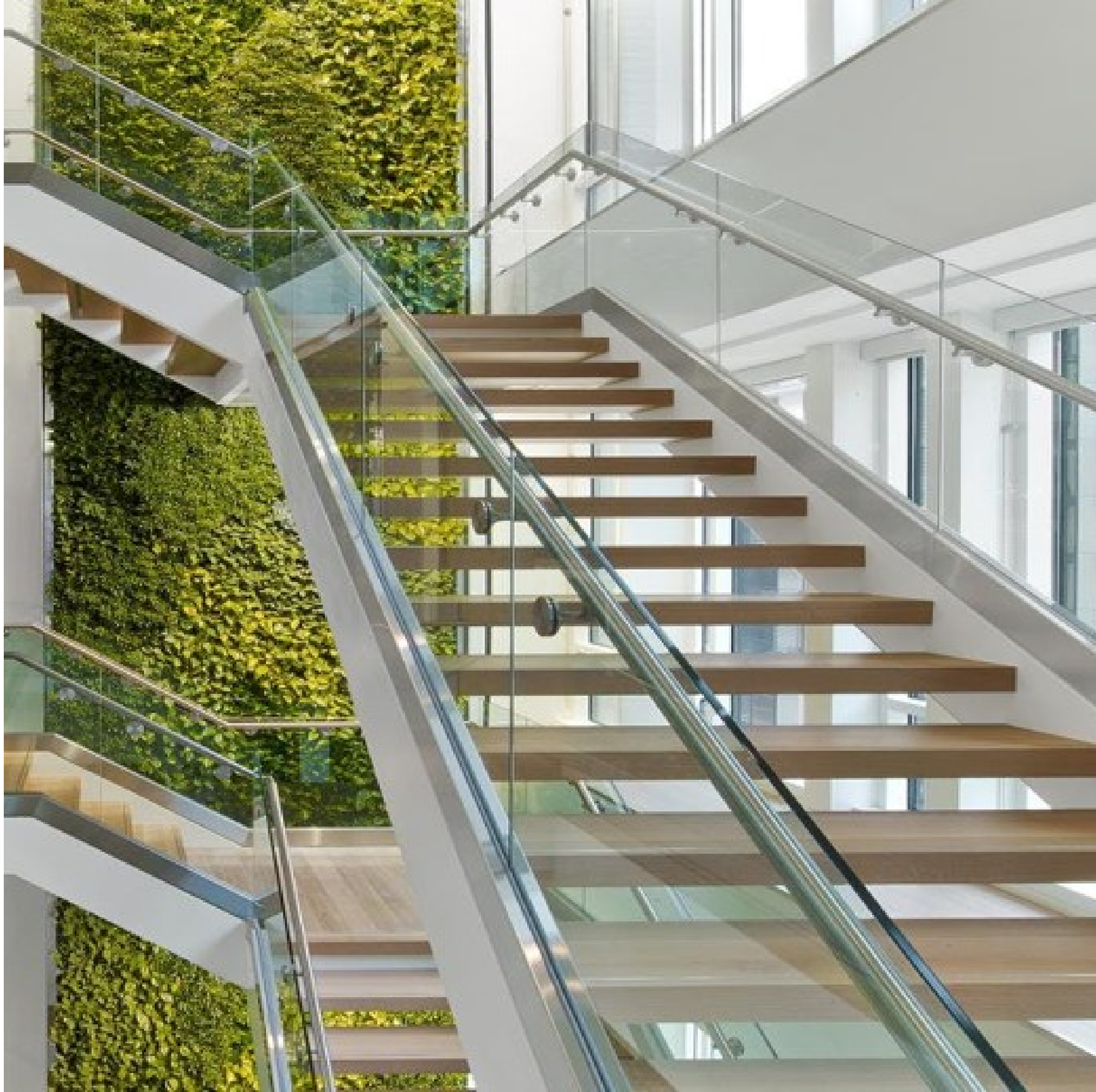

U.S. DEPARTMENT OF ENERGY BATTELLE

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Pacific Northwest NATIONAL LABORATORY

Research Background

Pacific Northwest NATIONAL LABORATORY

ABOUT | NEWS & MEDIA | CAREERS | EVENTS | SEARCH

RESEARCH | PEOPLE | PARTNER WITH PNNL | FACILITIES & CENTERS

Healthy Buildings Initiative

Making the case for building energy efficiency: considerations for occupant health and productivity

PNNL Website: https://www.pnnl.gov/projects/healthy-buildings

FEMP Website TBA

3-year program, Healthy Buildings Initiative, funded by the Department of Energy Federal Energy Management Program (DOE-FEMP)

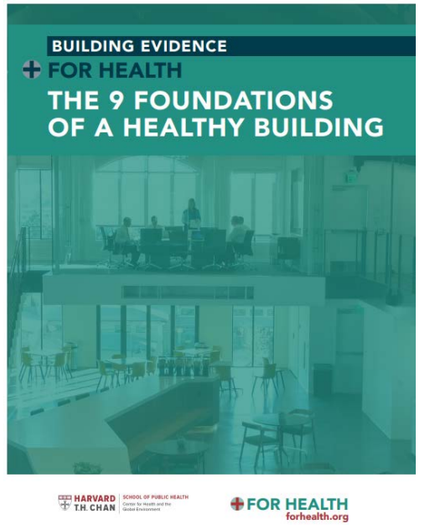
Objectives

Quantify and monetize potential productivity and employee gains.

Integrate indoor environmental quality (IEQ) outcomes with energy efficiency measures.

Develop a toolkit to help federal facilities make holistic decisions on building retrofits and operation.

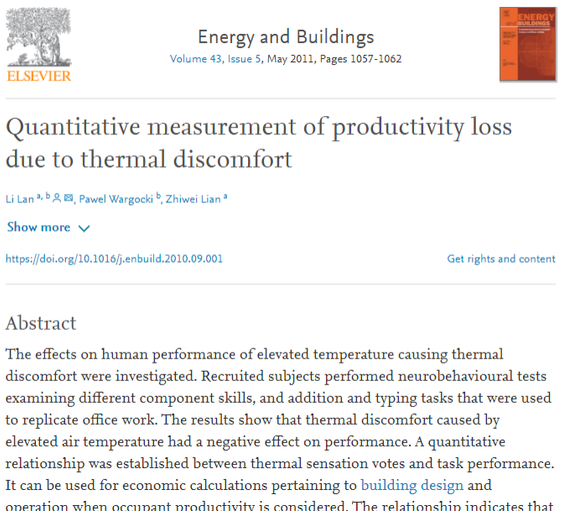
Industry Landscape and Challenges

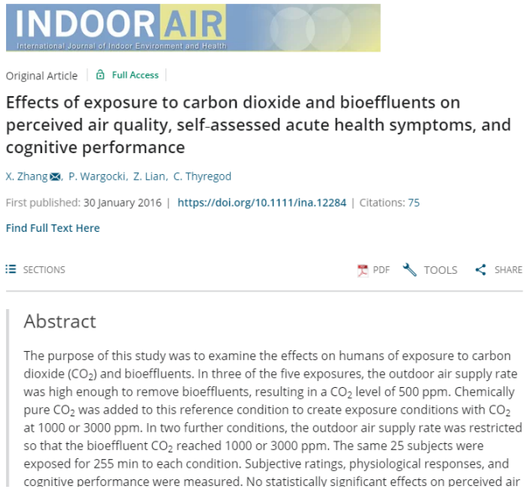


Business cases and design guides for general healthy building practices

https://stok.com/financial-case-for-high-performance-buildings/

https://9foundations.forhealth.org/9_Foundations_of_a_Healthy_Building.February_2017.pdf





Controlled laboratory studies on occupants under different IEQ conditions.

https://www.sciencedirect.com/science/article/pii/S0378778810003117

https://onlinelibrary.wiley.com/doi/full/10.1111/ina.12284

Industry Landscape and Challenges

Challenge

How to translate research to a specific building and valuate the benefits?

Business cases and design guides for general healthy building practices

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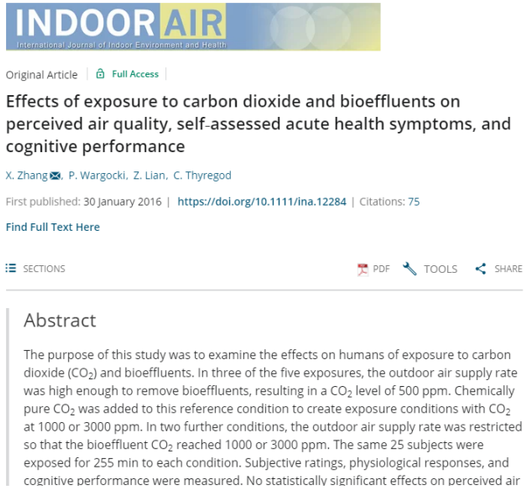

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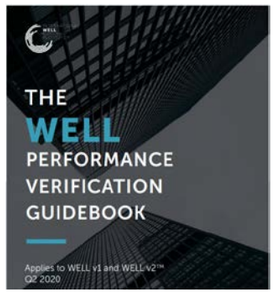
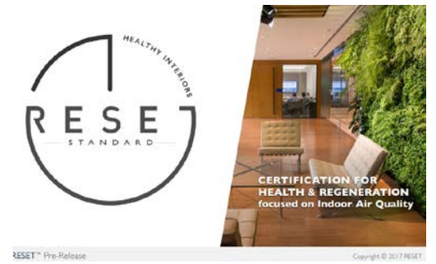
Industry Landscape and Challenges



WELL Performance Verification Guidebook

- 3rd party certified Testing Agent
- Entire facility, including mechanical spaces, etc.
- Once every three years for recertification

RESET Standard

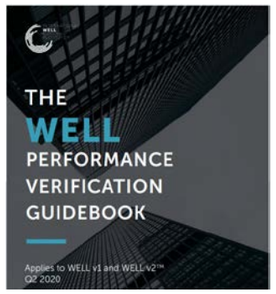


- Self-guided or Accredited Solutions Provider
- Open workspaces and common areas (not private office, lobby, washroom, or copy room)
- Continuous monitoring with 90% of daily averages meeting threshold to maintain
- Focus on indoor air quality (IAQ), more categories TBD

WELL Performance Verification: https://a.storyblok.com/f/52232/x/cc341e5b92/well-performance-verification-guidebook-with-q2-2020-addenda.pdf

RESET Standard: https://reset.build/download/RESET_Standard_v2_0_prerelease_170312.pdf

Industry Landscape and Challenges



Challenge

How to comprehensively evaluate the IEQ performance of a building at a low-cost?

- Duration
- Sample size
- Metrics

- 3rd party certified Testing Agent
- Entire facility, including mechanical spaces, etc.
- Once every three years for recertification

Challenge

IAQ monitoring is especially challenging[1]:

- Inconsistency in IAQ standards and guidelines
- A large number of different pollutants
- Lack of analysis linking pollutants to health effects
- Lack of measurement and monitoring technologies

- Self-guided or Accredited Solutions Provider
- Open workspaces and common areas (not private offices, bathroom, copy room)
- Continuous monitoring with 90% of daily averages meeting threshold to maintain
- Focus on indoor air quality (IAQ), more categories TBD

WELL Performance Verification: https://a.storyblok.com/f/52232/x/cc341e5b92/well-performance-verification-guidebook-with-q2-2020-addenda.pdf

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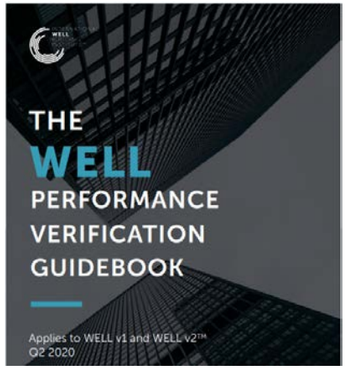
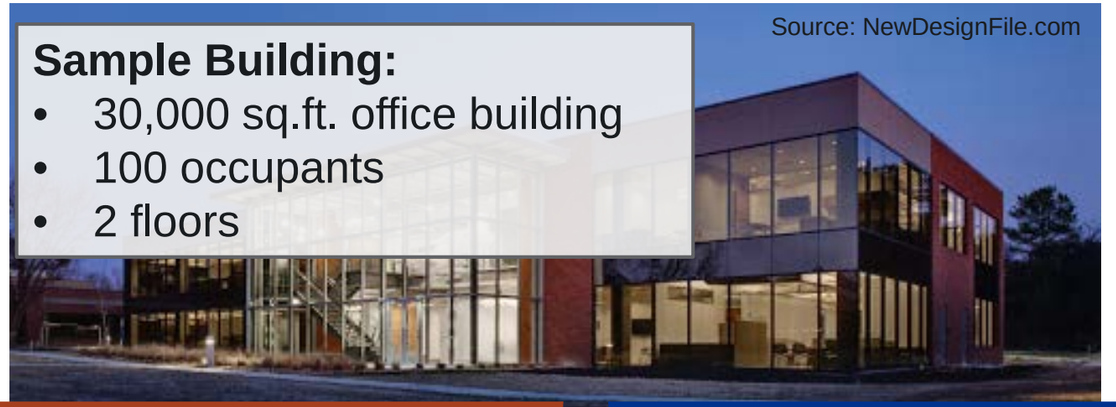
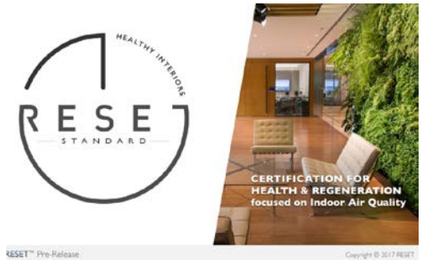
Industry Landscape and Challenges





Sample Building:

- 30,000 sq.ft. office building
- 100 occupants
- 2 floors



Category	Metrics (prereq.)	Metrics (credits)	Duration	Sample Size
Indoor Air Quality	8	4	1 hour	2
Electric Light	1	0	Spot measure	50
Daylight	0	1	Spot measure	41
Thermal Comfort	3	0	10 minutes	7
Acoustic Comfort	0	4	5 minutes	3

Category	Metrics	Duration	Sample Size
Indoor Air Quality	3	90 days +	6
Electric Light	-	-	-
Daylight	-	-	-
Thermal Comfort	2	Continuously	6
Acoustic Comfort	-	-	-

Pilot Tests

Building A

Vintage: 2017
Size: 26,000 sq.ft.
Location: Northwest
Occupants: 92

Building B

Vintage: 1970
Size: 29,000 sq.ft.
Location: Northwest
Occupants: 80

Building C

Vintage: 1940’s
Size: 110,000 sq.ft.
Location: South Central
Occupants: 250

Building D

Vintage: 1917
Size: 764,000 sq.ft.
Location: Mid-Atlantic
Occupants: 2,200

Building E

Location: South Central
Size: ~96,000 sq.ft.
Occupants: 478

Building F

Location: Mid-Atlantic
Size: ~38,000 sq.ft.
Occupants: 188

Building G

Location: Mid-Atlantic
Size: ~115,000 sq.ft.
Occupants: 575

Note

Seven samples is not enough to make sweeping conclusions but offers valuable observations

Pilot Tests

Building A

Vintage: 2017
Size: 26,000 sq.ft.
Location: Northwest
Occupants: 92

Building D

Vintage: 1917
Size: 764,000 sq.ft.
Location: Mid-Atlantic
Occupants: 2,200

Objective

1. Identify **minimum** sample duration (# of weeks of monitoring) that adequately characterizes building
2. Identify **minimum** sample size (# of sampling locations) that adequately characterizes building

This case study will look at CO_2 and thermal comfort as sample metrics

Building C

Vintage: 1940's
Size: 110,000 sq.ft.
Location: South Central
Occupants: 250

Building G

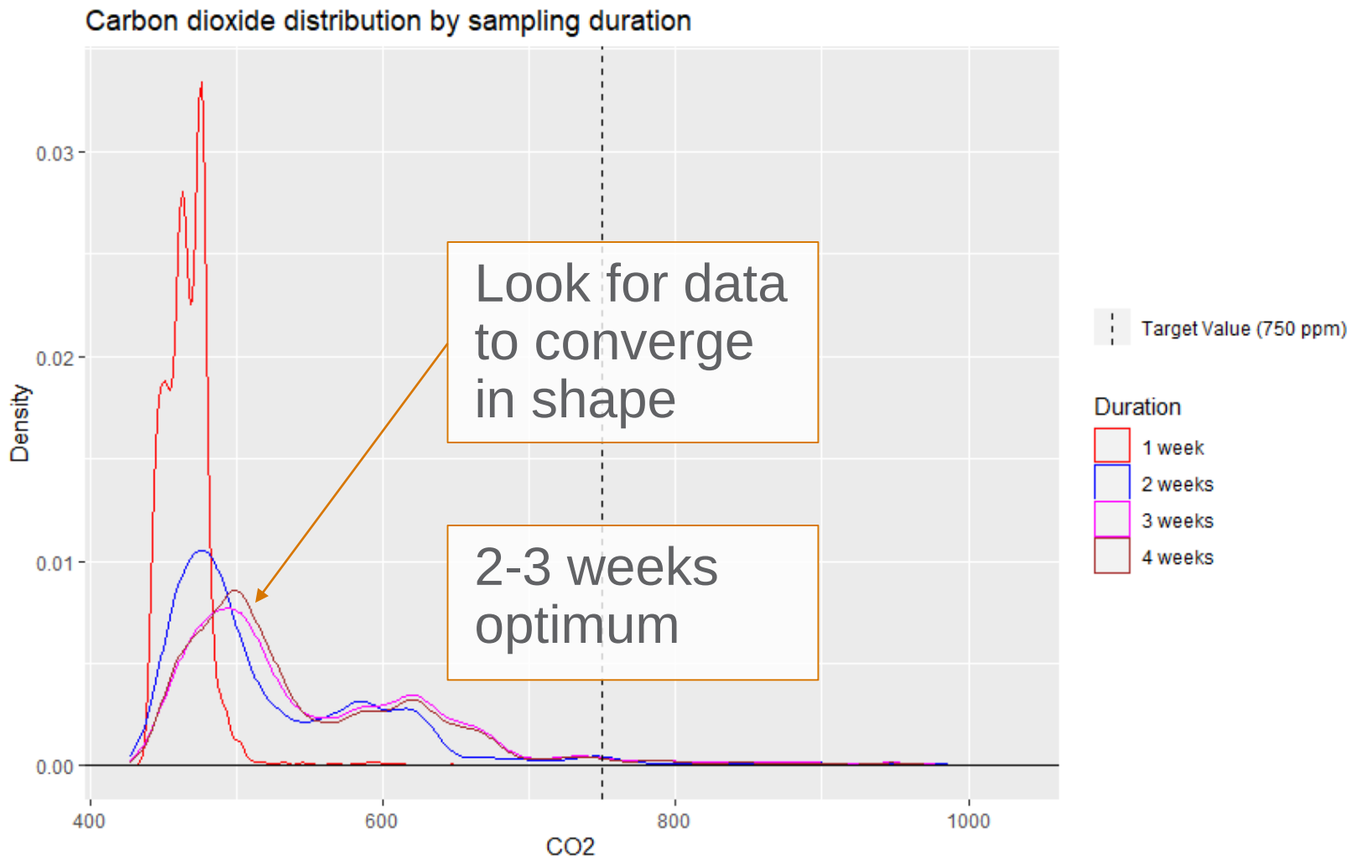
Location: Mid-Atlantic
Size: ~115,000 sq.ft.
Occupants: 575

Note

Seven samples is not enough to make sweeping conclusions but offers valuable observations

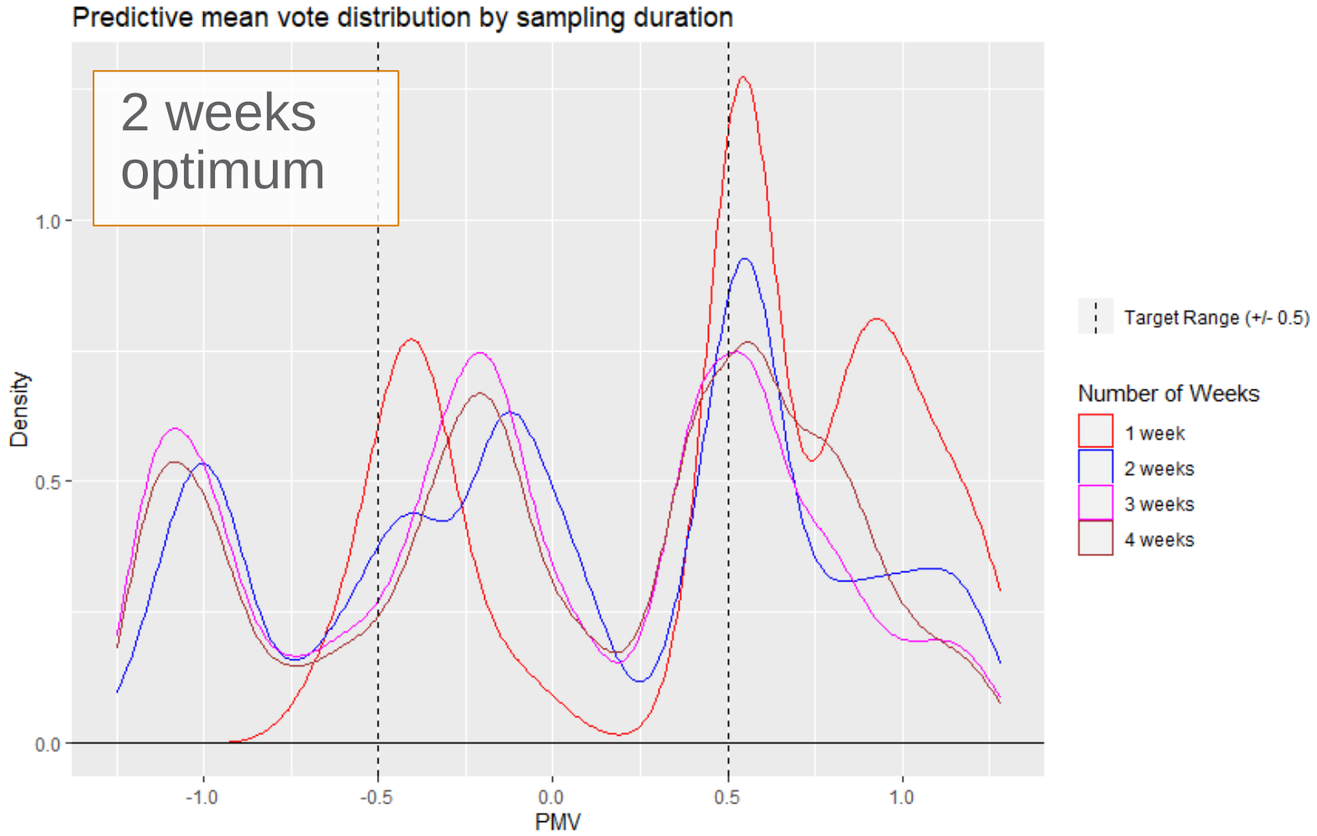
Identifying Optimal Sample Duration – CO_2

Building A



Identifying Optimal Sample Duration – Predictive Mean Vote (PMV)

Building A



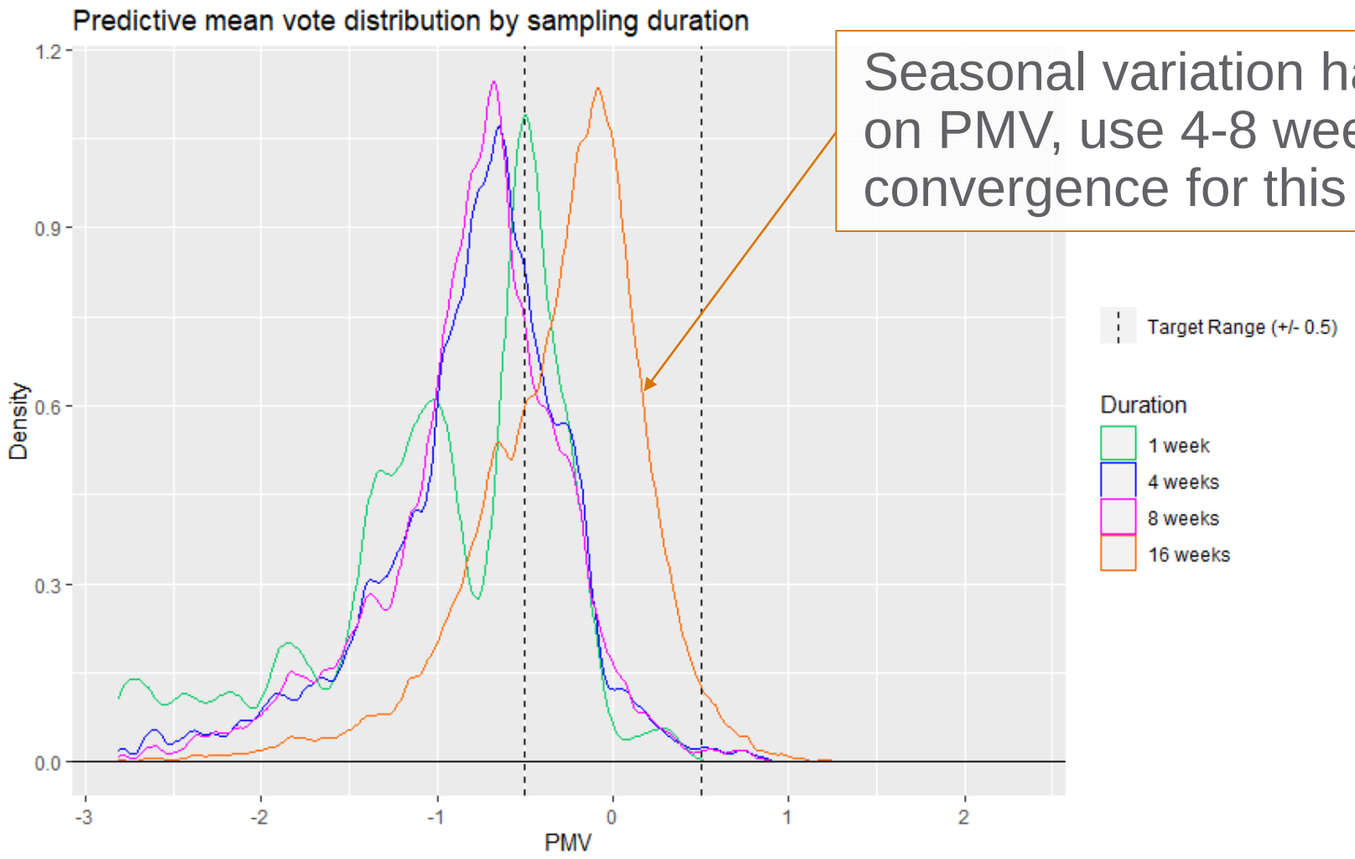
Predictive Mean Vote

PMV is a metric for **thermal sensation** on a scale of -3 (too cold) to +3 (too warm) calculated from temperature, relative humidity, clothing level, metabolic rate, and airflow rate.

The calculations are based on a large sample of empirical human responses. It has been adopted into an ISO standard and ASHRAE Standard 55.

Sample Duration - PMV

Building D



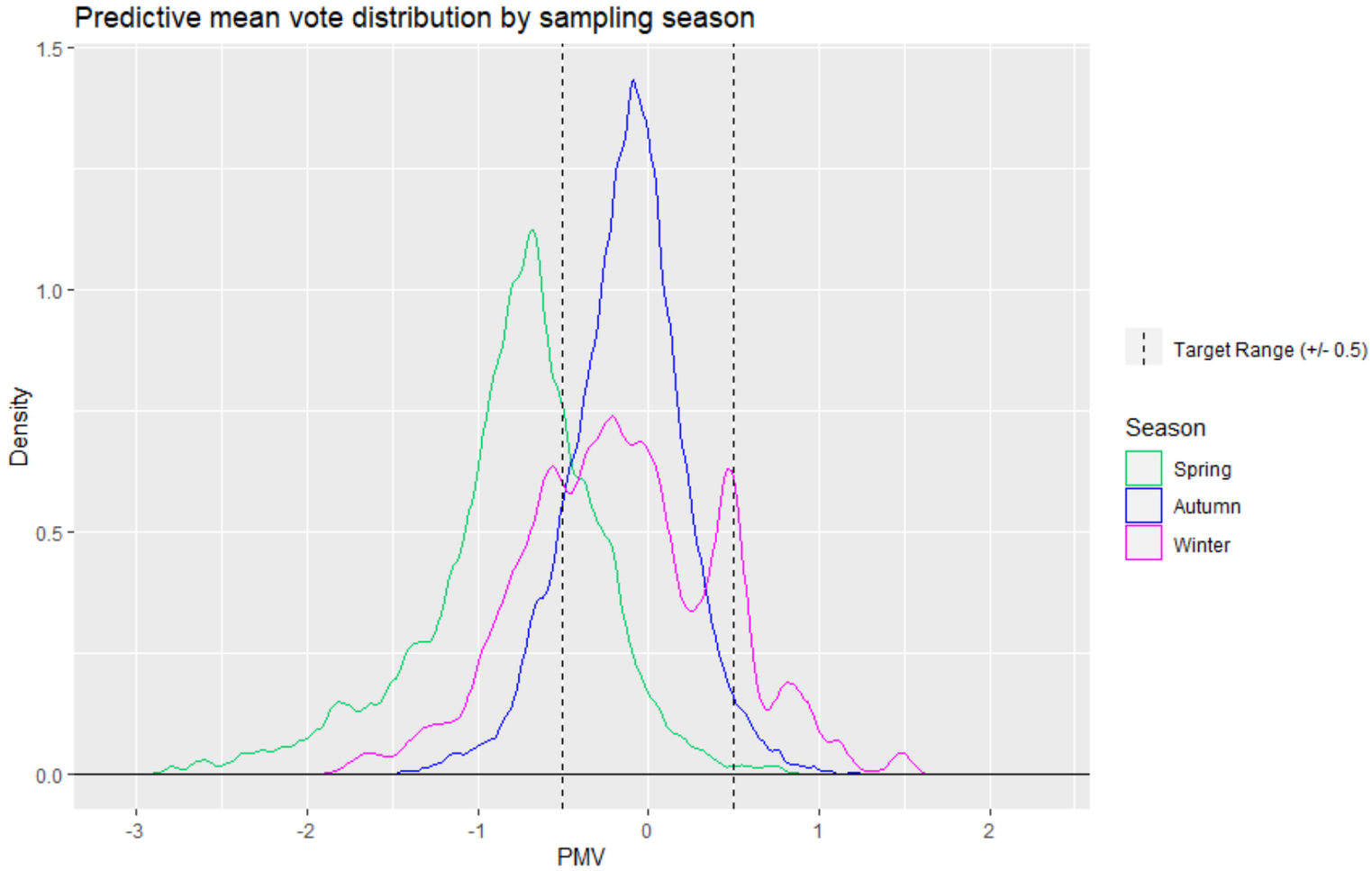
Seasonal variation has impact on PMV, use 4-8 weeks to find convergence for this exercise

Summary of Optimum Sample Duration Investigation

	CO_2		PMV	
	Duration Available (weeks)	Optimum Duration (weeks)	Duration Available (weeks)	Optimum Duration (weeks)
Building A	4	2-3	4	2
Building B	3	2	3	1
Building C	3	1-2	3	2
Building D	24	1-2	16	2-4
Building E	15	1	15	2-4
Building F	8	2-4	8	2-4
Building G	7	1	-	-
Average		**1.8**		**2.3**

Sampling PMV Across Seasons

Building D



Sample Duration Observations

- **Recommend 2 weeks of CO_2 collection**
  - Significantly more than the 1-hour IAQ monitoring duration from WELL and significantly less than the 90-day duration from RESET
  - With only 2 weeks, need to be prudent of non-standard events (holidays, events, etc.)

- **Recommend 2-3 weeks of PMV (temperature, humidity) monitoring and sampling in each season**
  - Significantly more than the 10-minute monitoring from WELL
  - Significant seasonal variation but data in more buildings needed to support observation (only one building collected seasonal data)

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Summary of Optimum Sample Size Investigation

	CO_2			PMV		
	Optimum CO_2 Sensor Quantity	Optimum Sq.ft. per Sensor	Optimum Occupants per Sensor	Optimum Sensor* Quantity	Optimum Sq.ft. per Sensor	Optimum Occupants per Sensor
Building A	4	7,000	23	4	7,000	23
Building B	2-3	10,000	27	2-3	10,000	27
Building C	3	37,000	83	2-3	44,000	100
Building D	5	153,000	440	10	76,000	220
Building E	2	48,000	239	15	6,000	32
Building F	2	19,000	94	4	10,000	47
Building G	5	23,000	115	20	6,000	29
Average (Buildings < 50k sq.ft.)		21,000	96		8,000	32
Average (Buildings > 50k sq.ft.)		71,000	213		42,000	87

* Sensors measure humidity and temperature and PMV is calculated from those values.

Sample Size Observations

- **Number of optimum sensor locations depends on size of building**
  - About 3-4x more per floor area/occupant in small buildings
  - WELL uses a size threshold and number of stories for sample size requirements
- **PMV needs more locations to reach optimum than CO_2,**
  - About 3x more for small buildings and 2x more for large buildings
- **CO_2 observation is less stringent than the ~5k sq.ft. per sensor in RESET and similar results to WELL**
- **PMV observation is typically less stringent than WELL requirements in small buildings**

Other Lessons Learned from Pilot Studies

- **Occupant preferences are not uniform**
  - We encountered spaces that were kept intentionally dark – excluded from analysis
  - Sometimes thermal comfort survey had different results than IEQ measurements – occupants have varying preferences and survey can be used as validation
- **Focus on areas where people are working**
  - Open offices, enclosed offices, conference rooms
  - Ignore restrooms, corridors, mechanical closets, etc.
- **Lighting samples during night underestimates performance**
  - Better for standards to guarantee performance but reflect occupants' actual experience
  - Weather and season are confounding and therefore more samples needed for exterior locations

Next Steps

- **Collecting data in more buildings: Collaborating with General Services Administration's pilot at Alcohol Tobacco & Firearms HQ**
  - GSA will be collecting data in accordance with the RESET Standard

Thank you

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