BEST PRACTICE FOR EVALUATING AND IMPROVING COMMERCIAL BUILDING PERFORMANCE

Chilled Water Systems Workshop

ASHRAE Brazil

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Sao Paulo, Brazil

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Presentation Outline

1) Characteristics of 2010 performance measurement protocols
2) The need for Best Practices Guide
3) Best practices 3-Level sequential process for energy, water, IEQ
4) Relationship to commissioning
5) Examples of Basic Evaluation, Diagnostic Measurement, Advanced Analysis
6) Conclusions/Questions

Characteristics of Protocols

- Why is it measured? ***The objective***
- What is to be measured and how is it to be measured? ***The metric***
  - ✓ Instrumentation
  - ✓ Spatial resolution
  - ✓ Temporal resolution

- What are the appropriate benchmarks?

Performance Evaluation/Benchmarking

PMP Field Test Case Studies

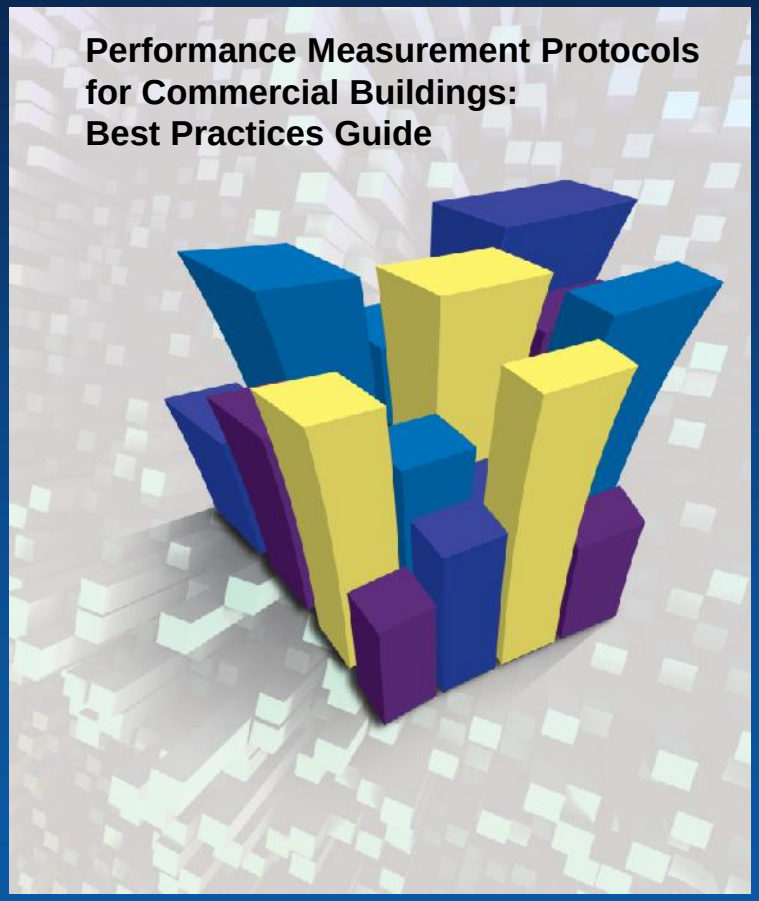
Texas A&M University

- Office building: 7 story, 11 516 m^2
- Basic protocols applied for energy, water, IEQ (Intermediate/Advanced only for IEQ)
  - ✓Basic Level spot measurements may be unnecessary
  - ✓Dynamic effects made IEQ interpretation inconclusive
  - ✓Practical, procedure-oriented protocols needed

Kresge Foundation Complex, Troy, Michigan

- Focus on CBE occupant surveys

Performance Measurement Protocols for Commercial Buildings: Best Practices Guide



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Characteristics of Best Practices Guide

- Implementation guide for protocols
- Focus on performance improvement, not just measurement
- Practical, step-by-step, sequential procedure
- Provides guidance, tools, aids for engineers, facility managers and operators
- Supports integrated commissioning (EBCx)
- Standardized forms, worksheets, checklists

Measure Categories

- Energy
- Water
- IEQ Thermal Comfort
- IEQ Indoor Air Quality (IAQ)
- IEQ Lighting/Daylighting
- IEQ Acoustics

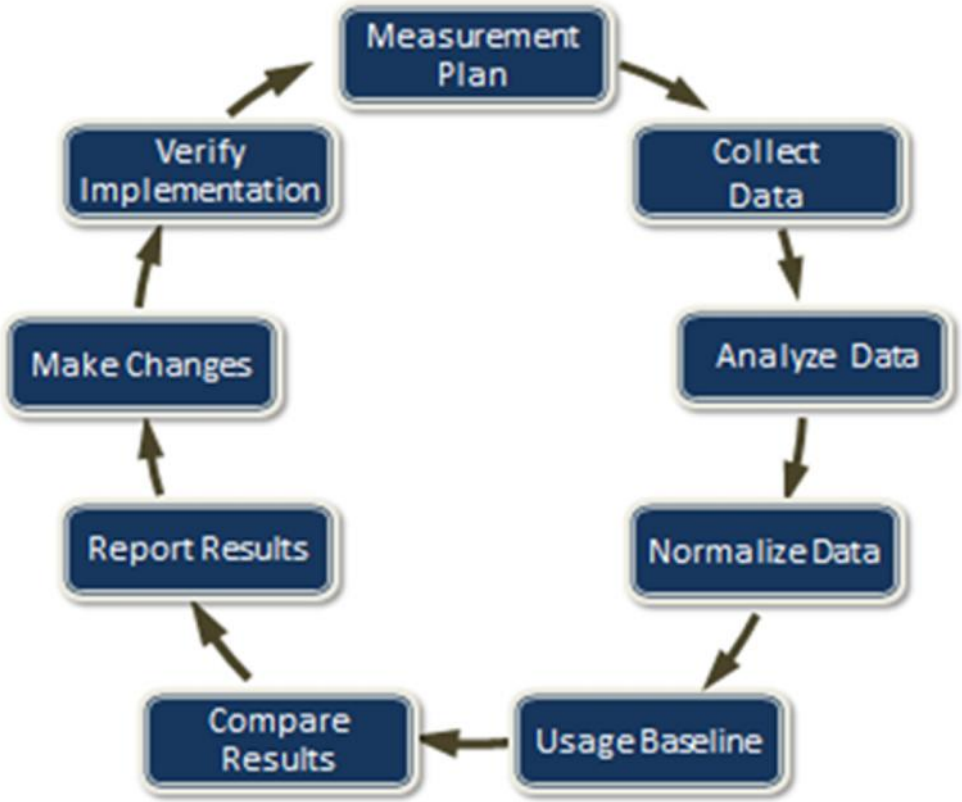
Three-Level Sequential Process is integrated with Cx Process

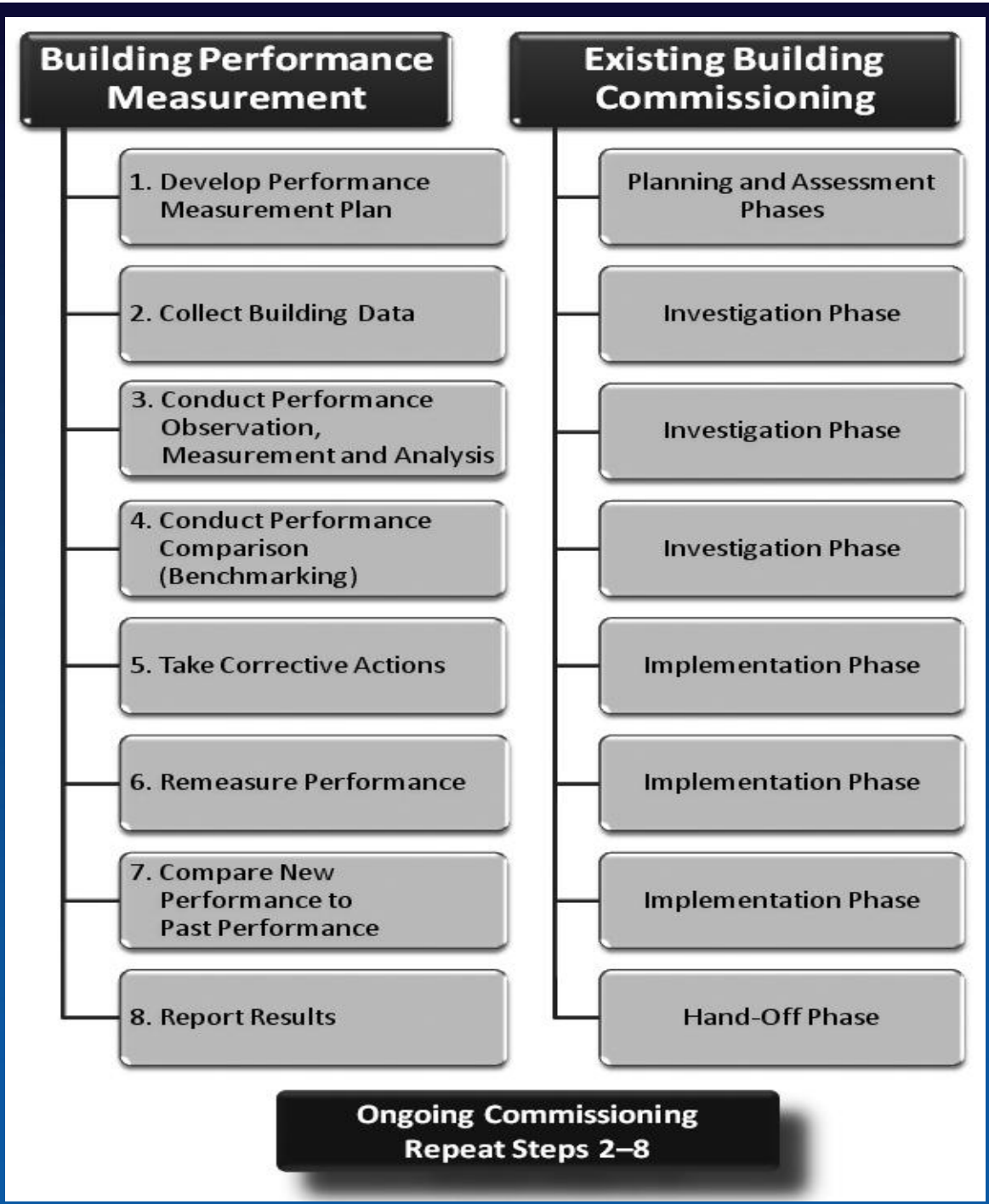
- ***Basic Evaluation*** *(indicative)*
  - ✓Observations of building characteristics
  - ✓Occupant perceptions
  - ✓Utility bills
- ***Diagnostic Measurement*** *(diagnostic)*
  - ✓Physical measurements for diagnostics to identify how performance may be improved
- ***Advanced Analysis*** *(investigative)*
  - ✓Results of first two levels, plus professional investigation to identify specific improvements

Seven-Step Procedure

1) Collect building characteristics
2) Performance observation, measurement, analysis
3) Performance comparison – benchmarking
4) Identify issues needing correction and take corrective action
5) Re-measure performance
6) Compare new to past performance
7) Report results

Ongoing Commissioning Process




Building Performance Measurement
Existing Building Commissioning
1. Develop Performance Measurement Plan
Planning and Assessment Phases
2. Collect Building Data
Investigation Phase
3. Conduct Performance Observation, Measurement and Analysis
Investigation Phase
4. Conduct Performance Comparison (Benchmarking)
Investigation Phase
5. Take Corrective Actions
Implementation Phase
6. Remeasure Performance
Implementation Phase
7. Compare New Performance to Past Performance
Implementation Phase
8. Report Results
Hand-Off Phase
Ongoing Commissioning
Repeat Steps 2–8

Guide Structure

For each measure category and level:

- **Introduction**
  - ✓ Purpose and goal of activity
- **Performance Measurement Procedure**
  - ✓ Flowchart
  - ✓ Measurement plan
  - ✓ Data collection
  - ✓ Benchmarking
  - ✓ Reporting
- **Tools and Aids**
  - ✓ Worksheets and forms

Advice for Commissioning

TO THE COMMISSIONING TEAM

Collection of building energy data and its benchmarking should be included in the ***assessment and investigation phases of the EBCx process****. Documentation review, site surveys taken during the building walk-through, occupant surveys, and systems diagnostic testing should* ***confirm that the owner's performance requirements are met as set forth in the Current Facility Requirements****.*

The walk-through checklist and report formats in this Guide can supplement the tools used by the Cx team.

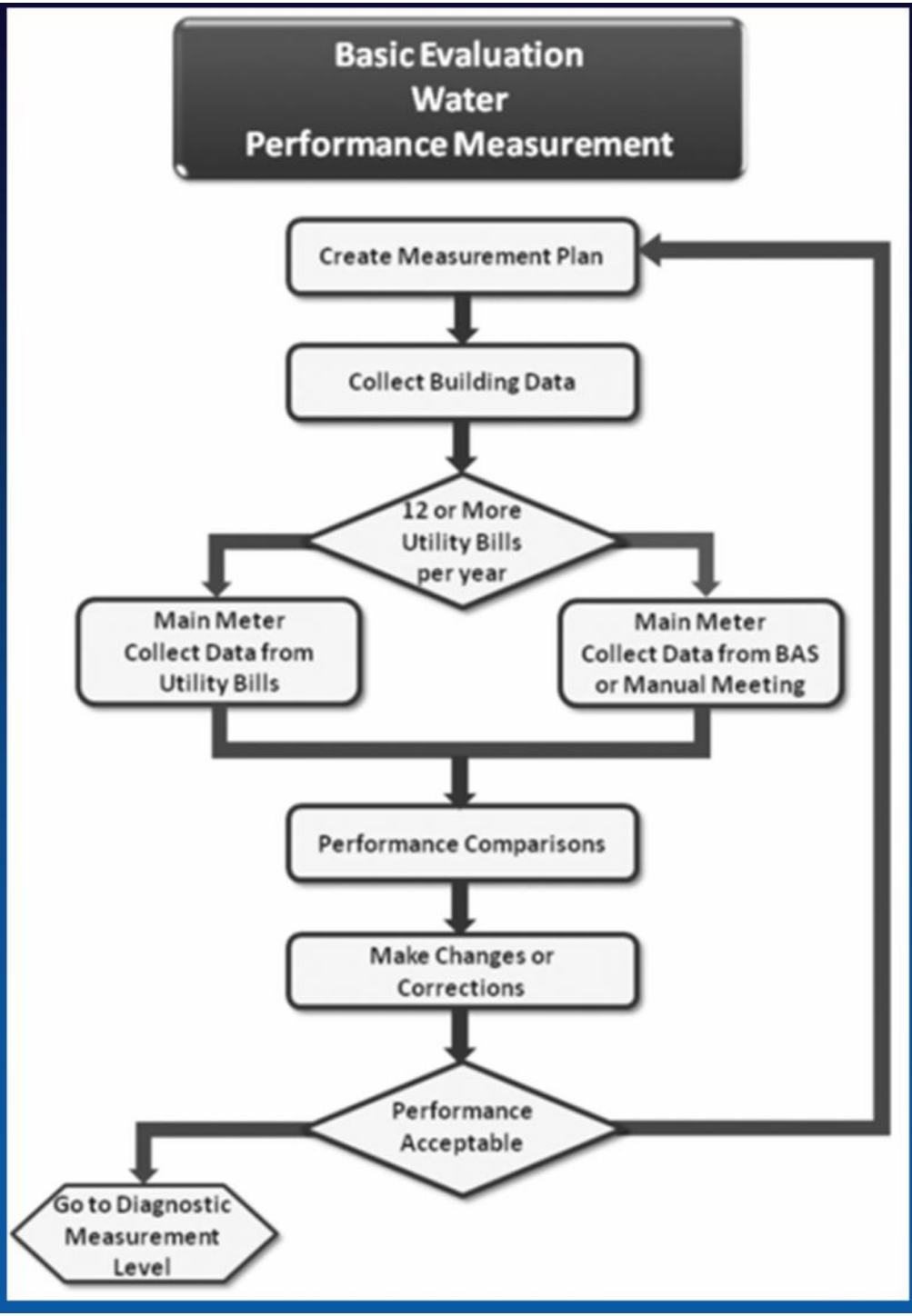
Basic Evaluation
Energy and Water

- **Energy**
  - ✓Energy bill use and cost analysis; no additional measurements
  - ✓Facility walk-through inspection (ASHRAE Level I audit)
- **Water**
  - ✓Utility meters verify performance
  - ✓Eliminate leaks and wasted usage
  - ✓Improve fixture efficiency, reduce landscape use

Table 2-2 Commercial Sector Floor Area and EUI Percentile

Building Use	Calculated, Weighted Number of Buildings, Hundreds	Calculated, Weighted Floor Area, 10^9 ft^2	Actual Number of Buildings, *N*	Calculated, Weighted Energy Use Index (EUI) Values Site Energy, kBtu/yr per gross square foot Percentiles 10th	25th	50th	75th	90th	Mean
Administrative/professional office	442	6.63	555	28.1	41	62	93	138	75
Bank/other financial	104	1.10	75	55.7	67	87	117	184	106
Clinic/other outpatient health	66	0.75	100	28.7	41	66	97	175	84
College/university	34	1.42	88	14.1	67	108	178	215	122
Convenience store	57	0.16	28	68.6	156	232	352	415	274
Convenience store with gas station	72	0.28	32	82.2	135	211	278	409	225
Distribution/shipping center	155	5.25	231	8.7	17	33	54	91	45
Dormitory/fraternity/sorority	16	0.51	37	36.3	65	74	100	154	90
Elementary/middle school	177	4.75	331	21.1	35	54	93	127	76
Entertainment/culture	27	0.50	50	1.7	29	46	134	418	95
Fast food	78	0.26	95	176.3	268	418	816	933	534
Fire station/police station	53	0.38	47	6.9	24	82	112	137	78

Adapted from **2011** ASHRAE *Handbook, HVAC Applications*, Chapter 36, “Energy Use and Management,” Table 2


Basic Evaluation
Water
Performance Measurement
Create Measurement Plan
Collect Building Data
12 or More Utility Bills per year
Main Meter Collect Data from Utility Bills
Main Meter Collect Data from BAS or Manual Meeting
Performance Comparisons
Make Changes or Corrections
Performance Acceptable
Go to Diagnostic Measurement Level

Basic Evaluation Water

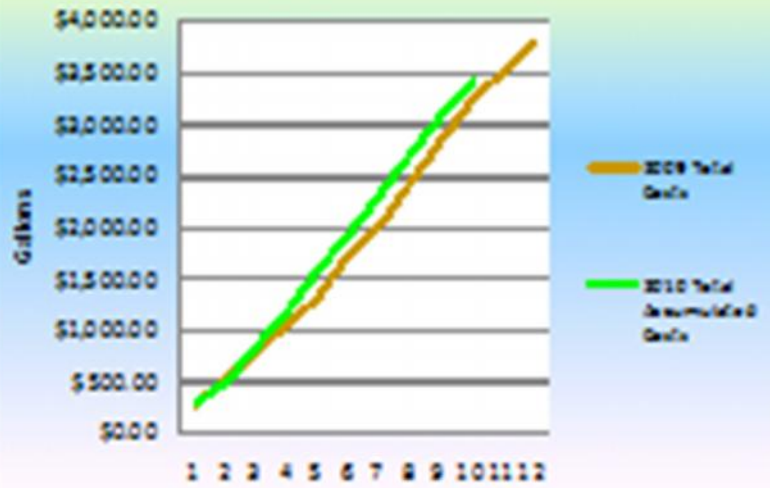
Table 2-3 Representative Water Use Indices, U.S. and Germany

User	DOE FEMP[1]		Association of German Engineers[2]	
	Goal	Units	Goal	Units
Airports	3	Gal/Passenger	49.2	Liters/Passenger
Apartment Houses	100	Gal/Person/Day	2.00	m^3/m^2/Year
Resort Apartment	60	Gal/Person/Day		
Boarding Houses	40	Gal/Person/Day		
Hotel	50	Gal/Guest/Day	182	Liter/Guest/Day
Lodging House	40	Gal/Guest/Day		
Motel	35	Gal/Guest/Day	167	Liter/Guest/Day
Motel with Kitchen	40	Gal/Guest/Day		
Laundry	550	Gal/Machine/Day		
Office	15	Gal/Employee/Day	.50	m^3/m^2/Year
Court Building			.50	m^3/m^2/Year
Data Centers			1.00	m^3/m^2/Year

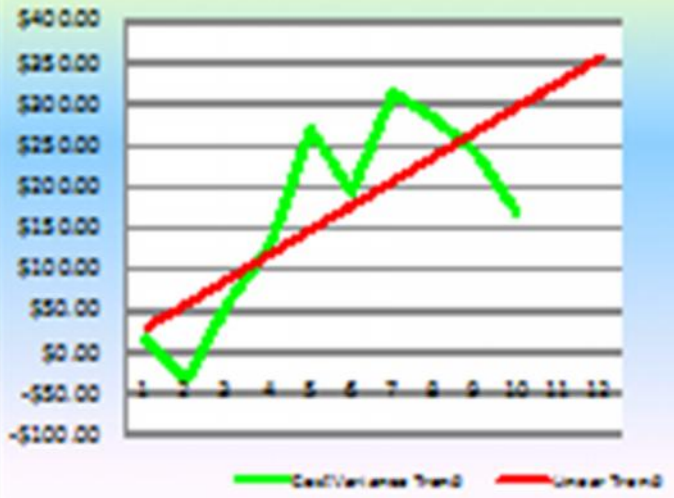
Water Cost Charts for: Tester Products

Date: 12/31/2010

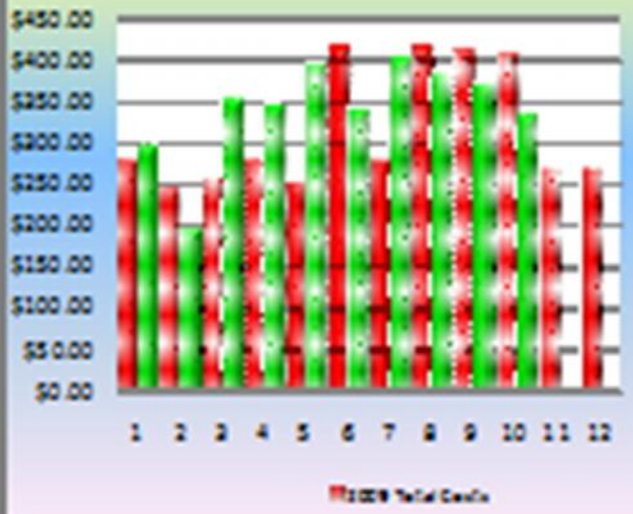
Total Annual Water Costs



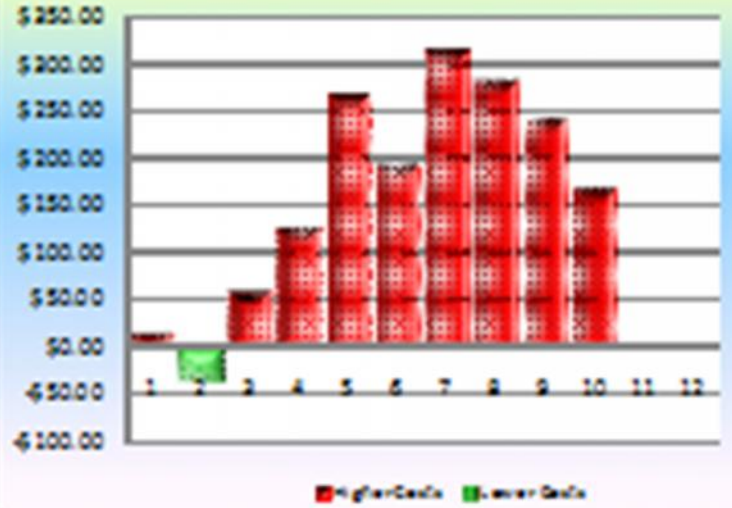
Water Cost Variance Trend



Total Monthly Water Costs



Water Cost Variance by Month



Basic Evaluation IEQ

Surveys, observations, ***no physical measurements***

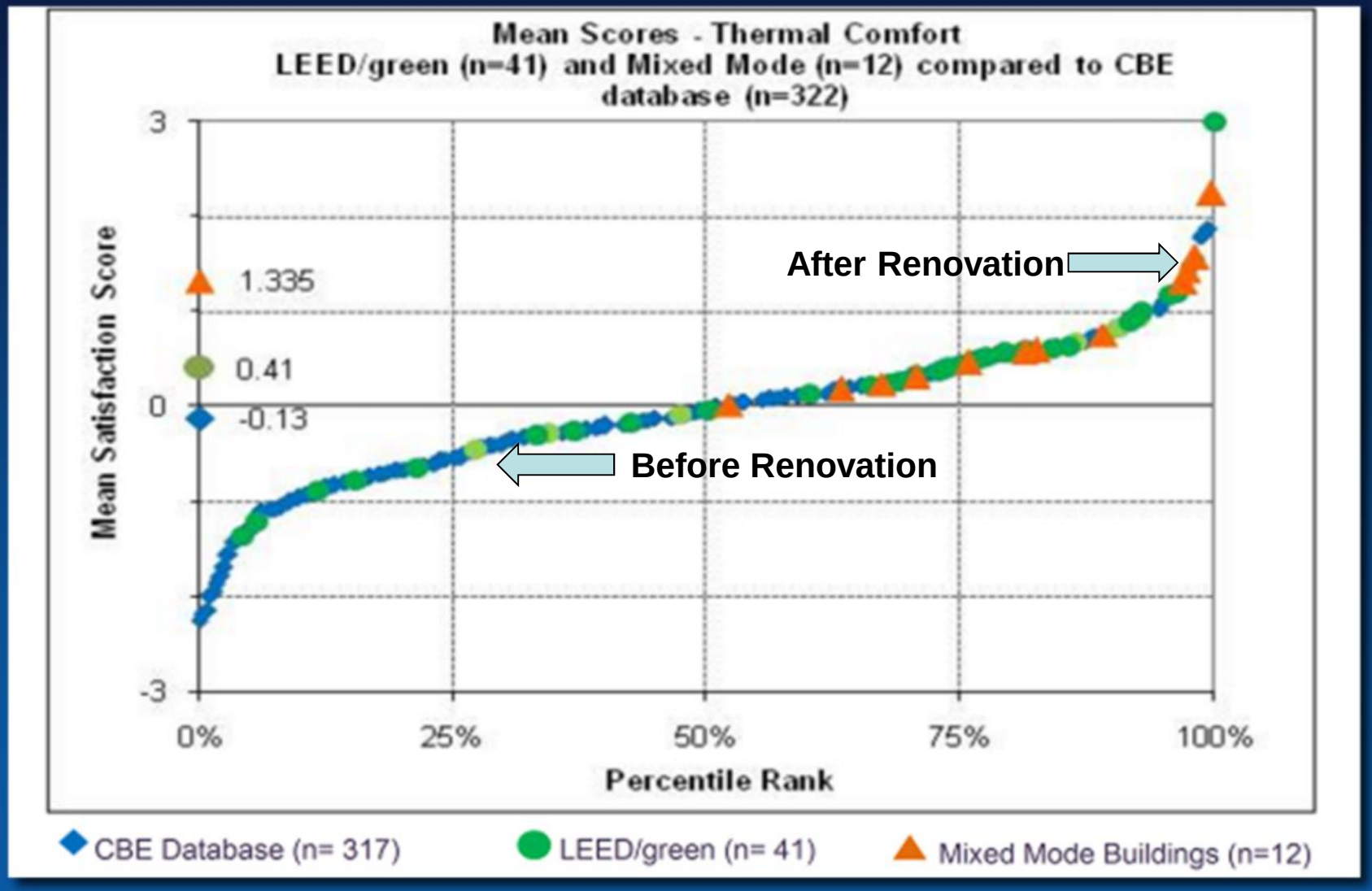
IEQ Category	Inspection Focus
Thermal comfort	• Fenestration (cold, hot surfaces or drafts) • Space configuration and furnishings (near windows or supply registers) • HVAC systems
IAQ	• Ventilation • Moisture management • HVAC systems • Building envelope pressurization • Dirt or contamination

Basic Evaluation IEQ

Surveys, observations, ***no physical measurements***

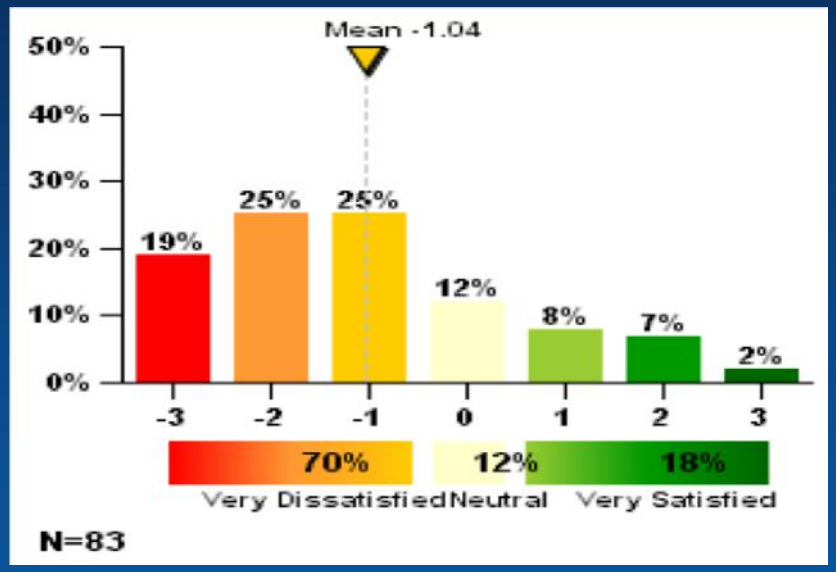
IEQ Category	Inspection Focus
Lighting/daylighting	• Quantity/quality of light • Glare • Controls • Lamps and ballasts • Maintenance
Acoustics	• Background noise • Noise intrusion • Acoustic privacy • Speech communication

Basic Evaluation THERMAL COMFORT



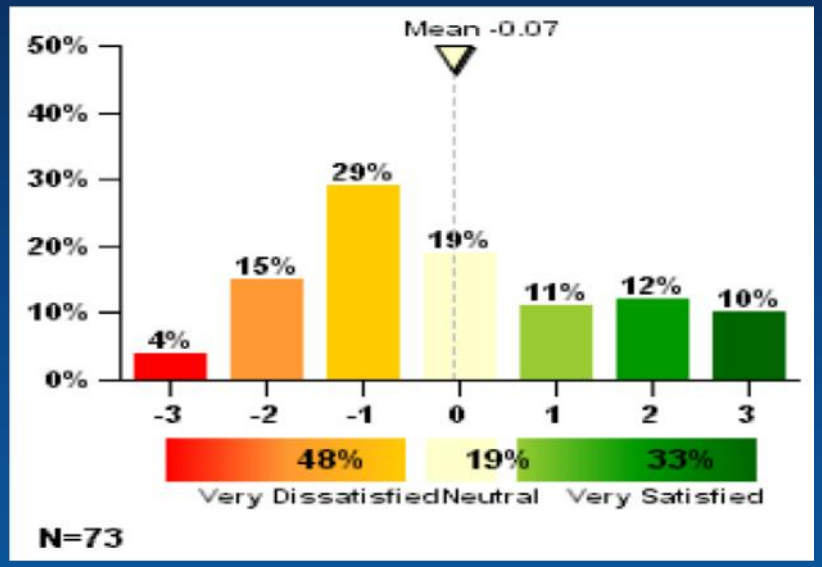
Basic Evaluation THERMAL COMFORT
Occupant Survey Results

Pre-Renovation: 2005



18 % Satisfied

Post-Renovation: 2010



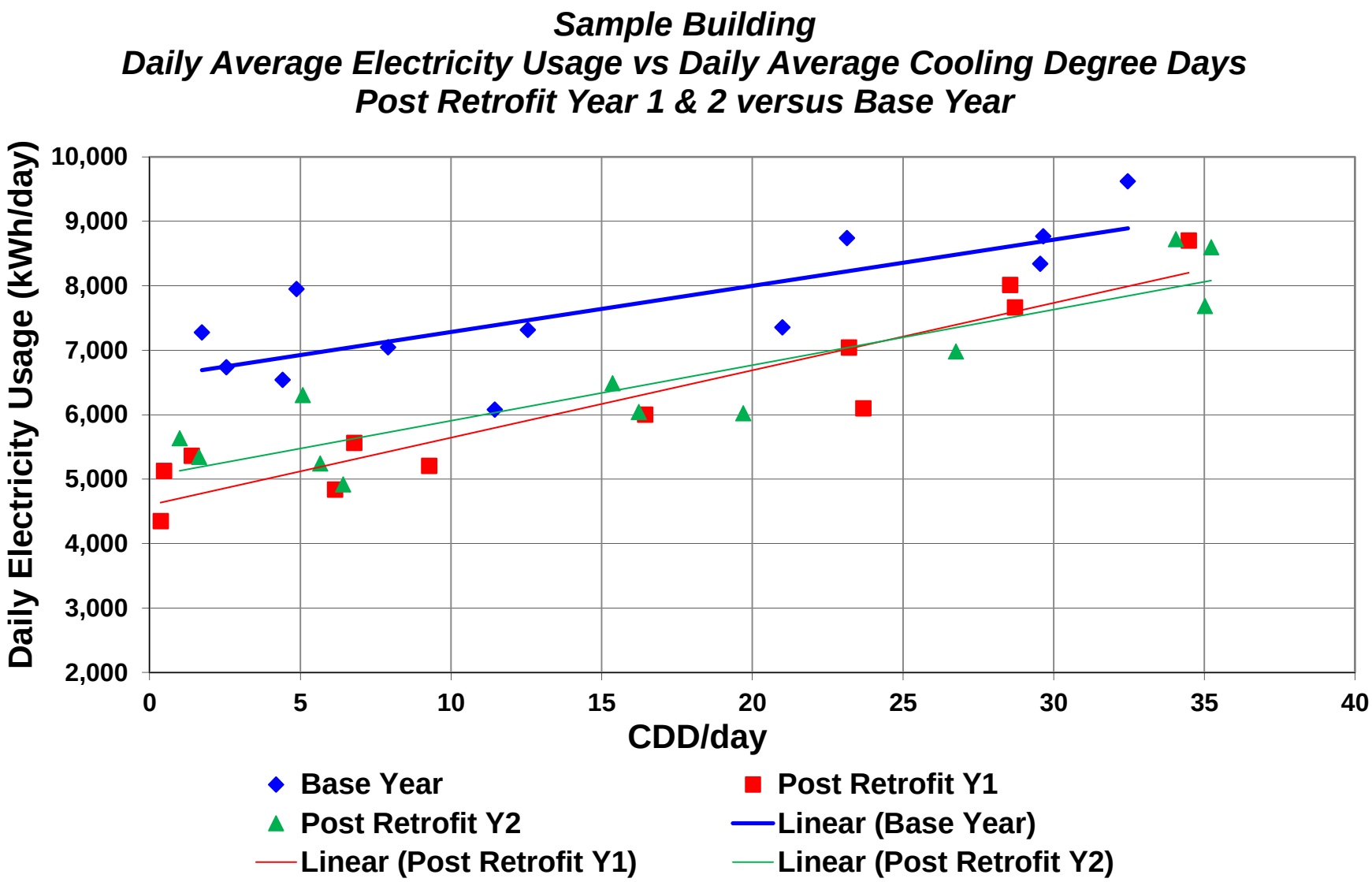
33% Satisfied

Basic Evaluation Acoustics Checklist

Background Noise
Noise Intrusion
Acoustic Privacy
Speech Communication

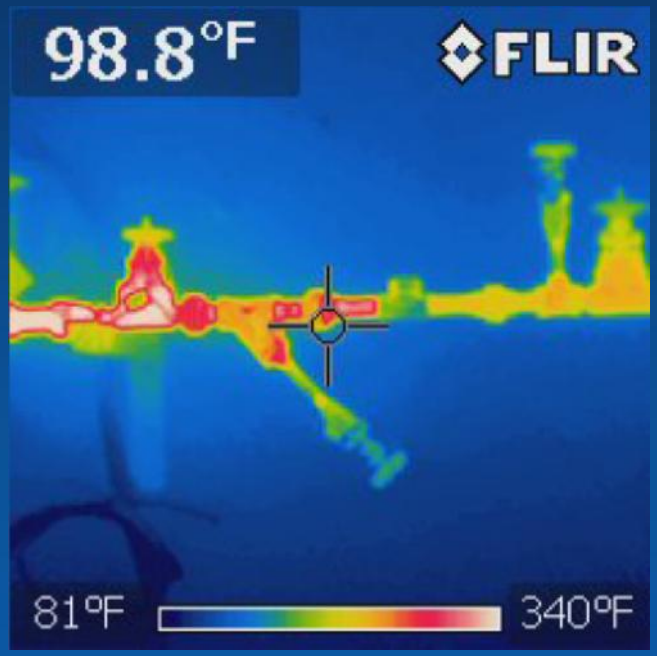
	Issue			*Recommendation*
Acoustic Privacy	Does sound privacy in your workplace interfere with employees getting their job done?			Proceed to DM and/or AA levels.
	Can you overhear other people talking on the phone from one workspace to another?			Establish a training program on telephone etiquette or introduce new telephone equipment with headset and quiet signaling features. If these "personal" corrective actions are not adequate, then proceed to the DM level.
	Can you overhear private conversations from neighboring areas or offices?			Designate acoustically isolated spaces for private conversations. If these "personal" corrective actions are not adequate, then proceed to the DM level.

Diagnostic Measurement ENERGY

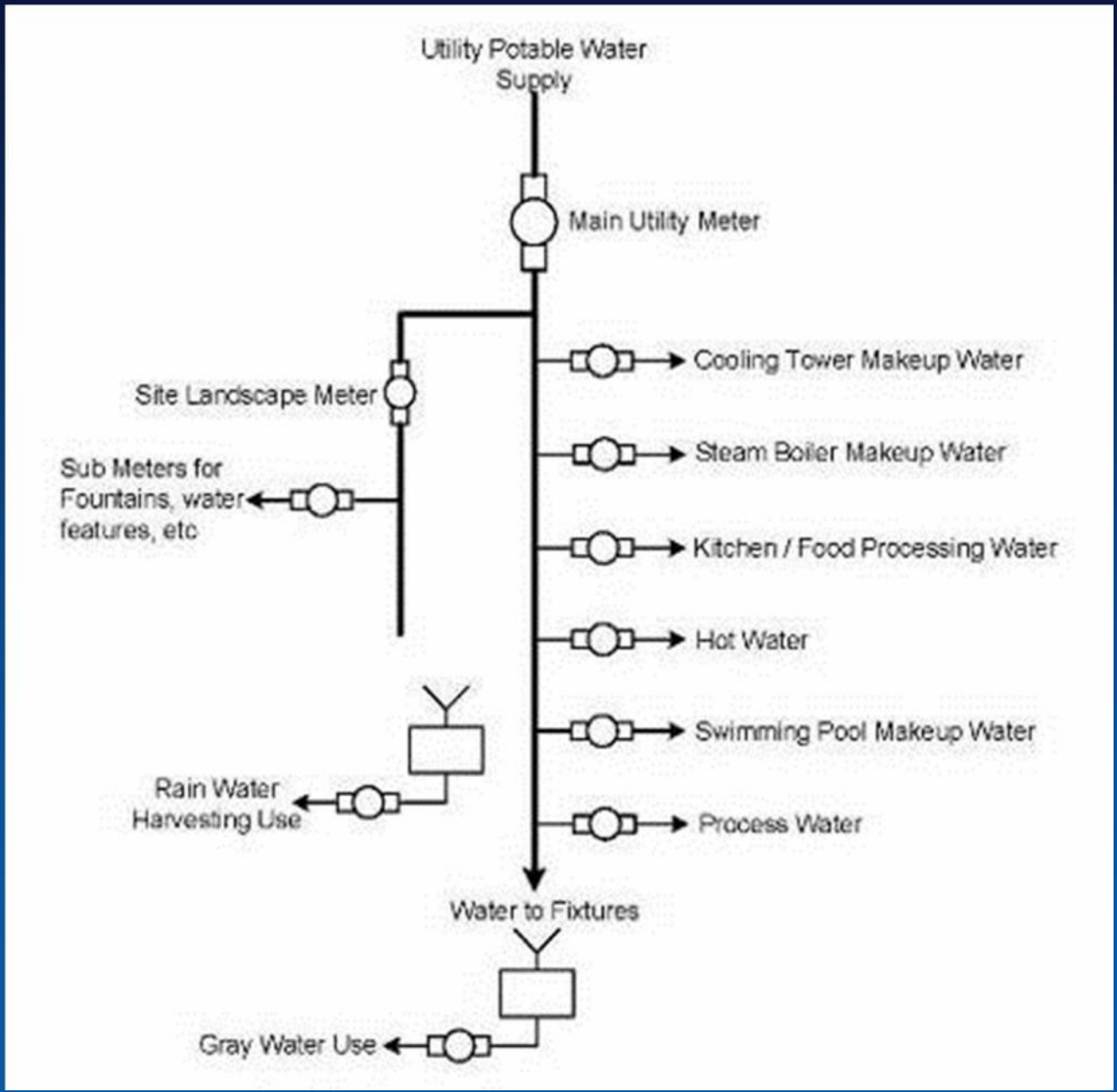


Diagnostic Measurement ENERGY

Thermal Image of Steam Trap in Office Building – Indicative of Proper Functioning



Diagnostic Measurement WATER



Diagnostic Measurement THERMAL COMFORT

Psychrometer for measuring temperature and humidity

Globe thermometer attached to temperature data logger

Diagnostic Measurement THERMAL COMFORT

Radiant Temperature Asymmetry Criteria

		Radiant temperature asymmetry, K			
Vertical air T diff,	Floor surface temp,	Warm ceiling	Cool ceiling	Cool wall	Warm wall
< 3 K	19 – 29 ºC	< 5 K	< 14 K	< 10 K	< 23 K
< 5 ºF	66 - 84ºF	< 9 ºF	< 25ºF	< 18ºF	< 41ºF

ASHRAE Standard 55-2010

Diagnostic Measurement IAQ

Measure ventilation for each ventilation system

- If BAS, log OA and compare to setpoints
- If no BAS, calibrate OA dampers and measure OA rate per Std. 111-2008
- For systems <1000 L/s supply air, measure OA annually. Adjust and remeasure per St. 111-2008
- Calibrate ventilation airflow sensors and test demand-control sequences annually

Diagn*ostic Measurement* IAQ

To improve performance

- Annual cooling system coil cleaning
- Particle filter upgrades (MERV 8-13)
- Condenser water cleaning
- Evaporator coil and drain pan cleaning
- Fan-powered reheat coil cleaning and filtration improvement
- Ozone filtering in non-attainment zones

Lighting Retrofit

Replace 4-lamp T12 with 2-lamp T5, add occupancy sensor

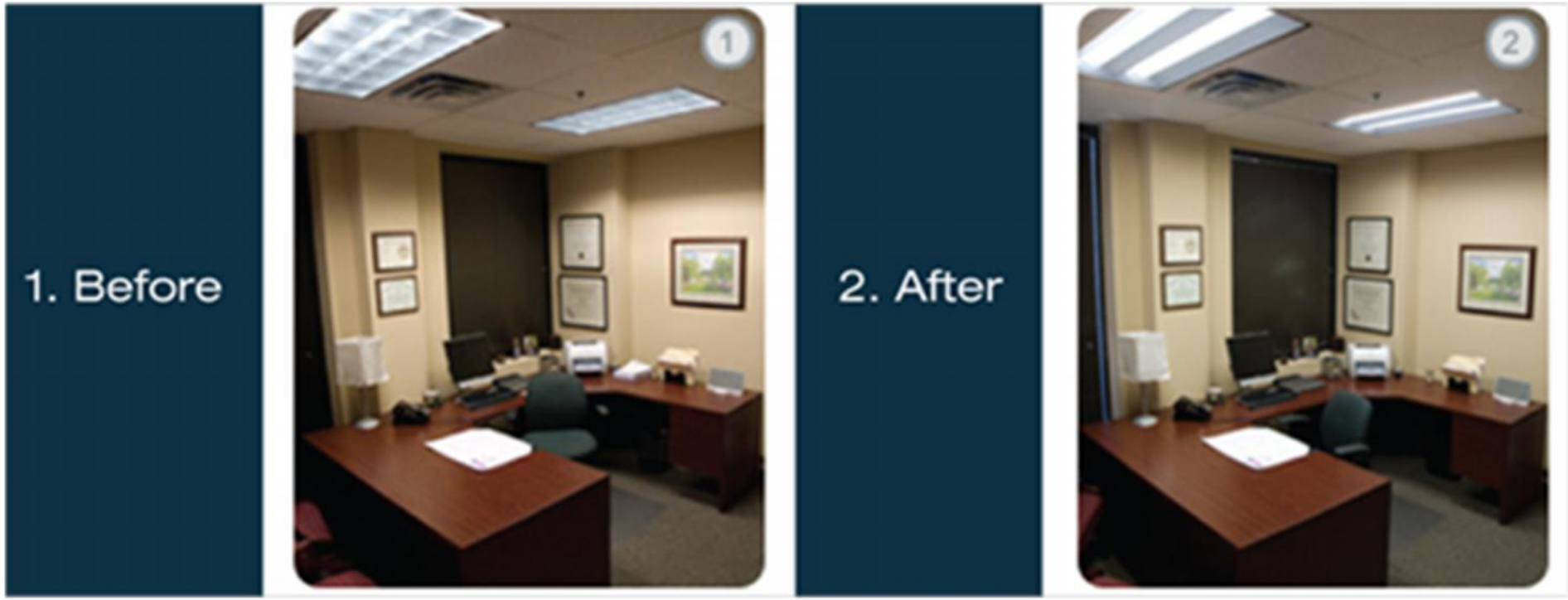


TABLE 3-2 Recommended A-Weighted, Equivalent Sound Criteria for Diagnostic Measurements

Room Types / Applications		Level 1 - Basic	
		Recommended L_{eq} (dB(A))	**Maximum L_{eq} (dB(A))**
Rooms with intrusion from Outdoor Noise Sources	Traffic noise and Aircraft flyovers	45	55
Apartments and Condominiums	Living areas	35	45
	Bathrooms, kitchens, utility rooms	40	50
Hotels/Motels	Individual rooms or suites	35	45
	Meeting/banquets rooms	35	45
	Corridors and lobbies	45	55
	Service/support areas	45	55
Office Buildings	Executive and private offices	35	45
	Conference rooms	35	45
	Teleconference rooms	30	35
	Open-plan offices	45	50
	Corridors and lobbies	45	55

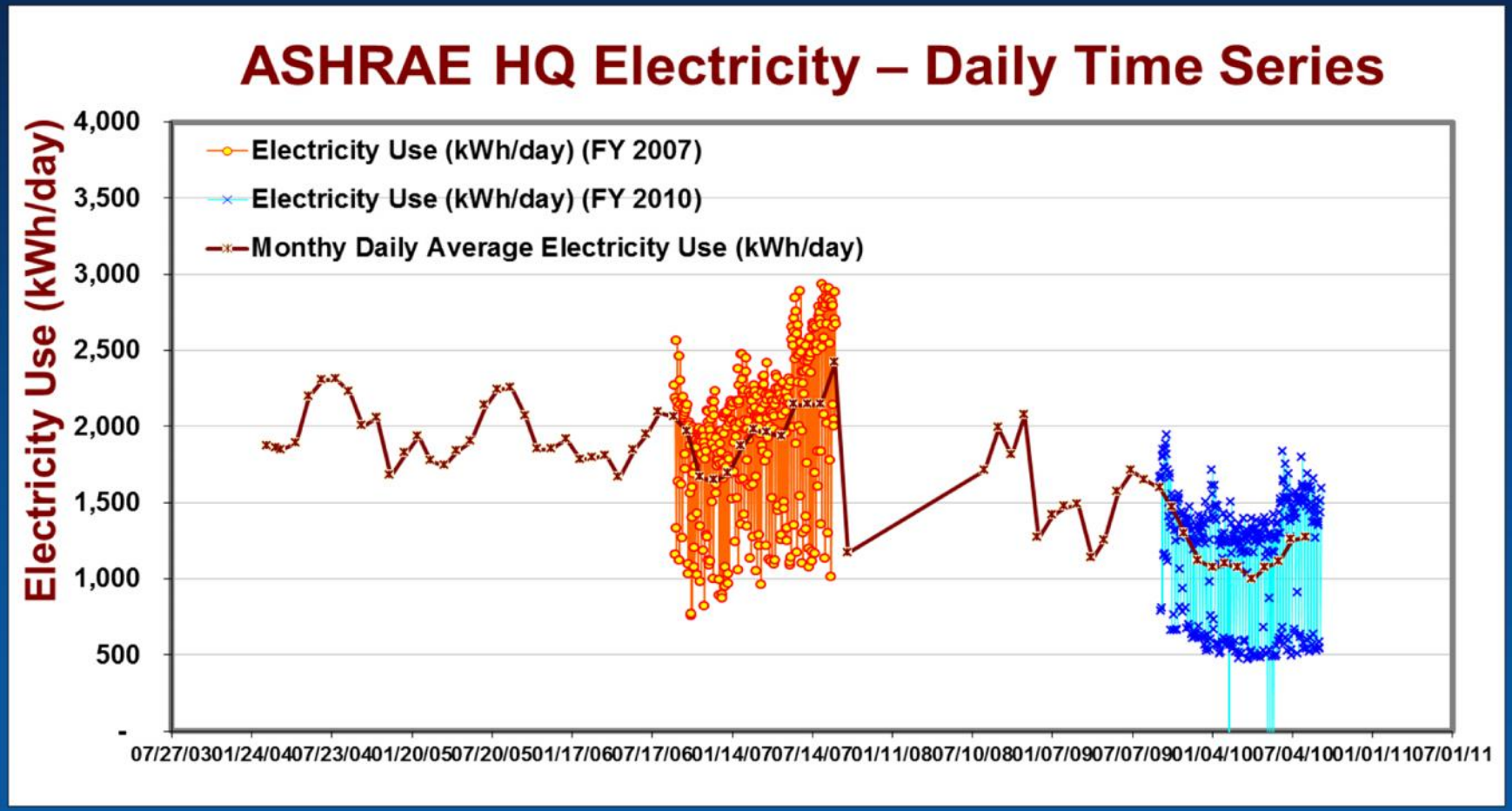
Advanced Analysis ENERGY

Uses the Universal Translator to

- Synchronize multiple interval data streams
- Integrate data from data-logging systems and BAS
- Create stacked time series charts from interval data to observe behavior of multiple systems over time
- Create X-Y scatter plots from interval data

Advanced Analysis **ENERGY**

Daily-Average Energy Use Pre- and Post Renovation

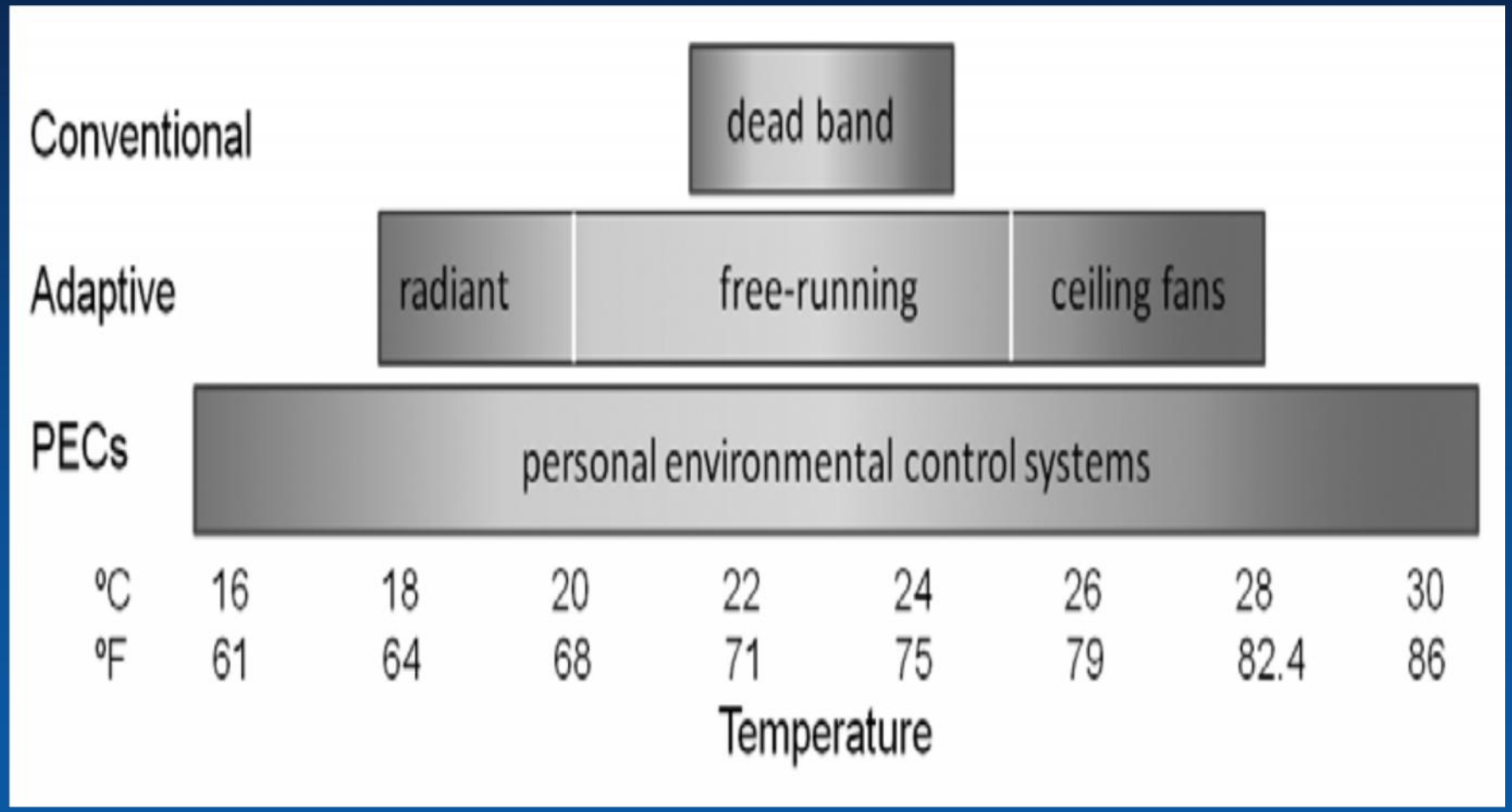


Data Analysis and Water-Use Calculations

- **Leak calculations**
  - ✓ Leak rate table, Fig. F-5
- **Plumbing fixture water use**
  - ✓ FTE occupants by gender, Table F-2
- **Cooling tower water use**
  - ✓ Total HVAC load
  - ✓ Condenser water flow rate and differential temp.
  - ✓ Concentration cycles
- **Landscape water use**
  - ✓ Evapotranspiration rate, irrigation system type

Advanced Analysis THERMAL COMFORT

Extended Thermostat Dead Band Zones



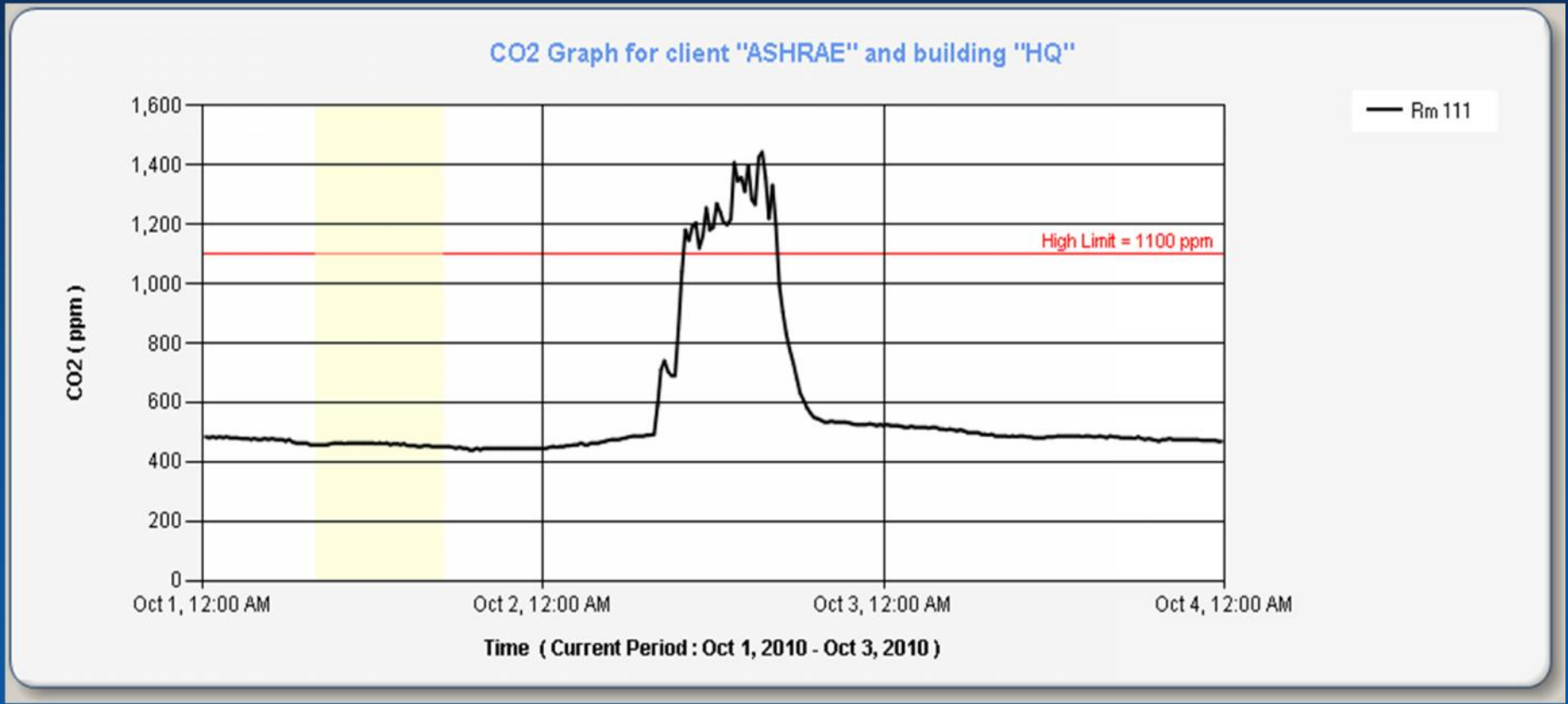
Adaptive Comfort Control - Increase in Acceptable Temperature Limits

Mean Air Speed	0.6 m/s	0.9 m/s	1.2 m/s
Temperature Increase	1.2 C (2.2 F)	1.8 C (3.2 F)	2.2 C (4.0 F)

Advanced Analysis THERMAL COMFORT
PEC Devices: fans, foot-warmer

Advanced Analysis **IAQ**

Continuous Measurement of CO_2 Education Center Conference Room



Advanced Analysis ACOUSTICS
Sound Isolation

Conclusions

- Performance Measurement Protocols provide useable, standardized protocols for consistent evaluation of energy, water, IEQ
  - ✓ *Need clarification and further testing*
- Best Practices Guide provides detailed, systematic, practical procedures to implement PMPs
  - ✓ *In context of Existing Building Cx*
  - ✓ *Continuing guidance for energy and operating cost reduction throughout building life*

QUESTIONS??

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