

APRIL 18, 2016

APPLYING SUSTAINABILITY PRACTICES TO
LIGHTING RETROFITS
IN THE UW TOWER

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A GREEN SEED FUNDED PROJECT

AT THE UNIVERSITY OF WASHINGTON

2015-2016 ACADEMIC YEAR

UW TOWER: A COMPLEX LIGHTING ENVIRONMENT

Criteria for Improvement

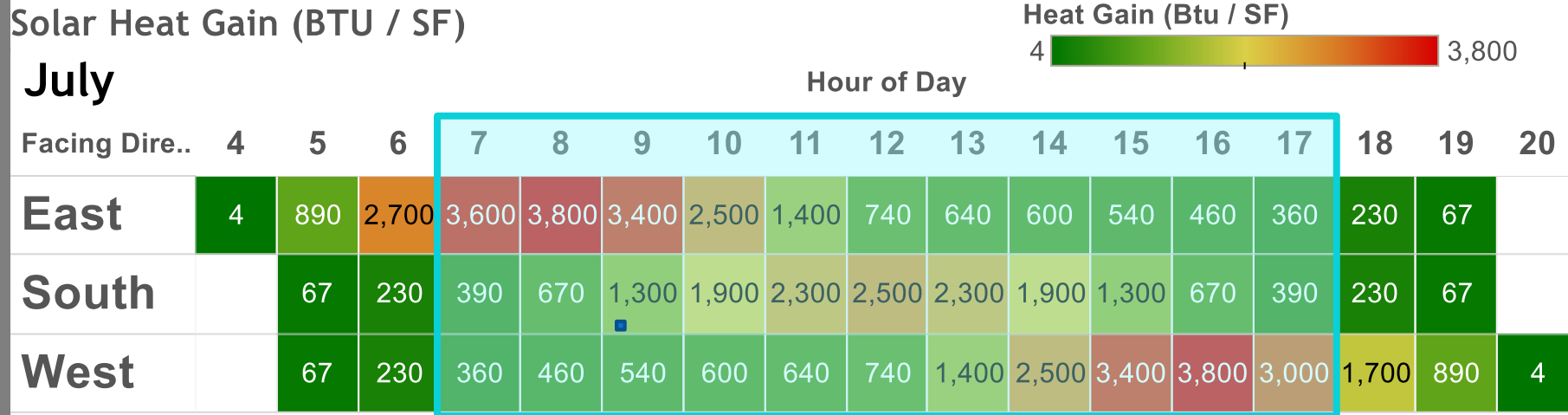
- Energy Consumption: ~\$1.1 million, 16.5 million KWh / yr
- Evidence of excessive illuminance, occupant discomfort
- Open office structures, vastly different floorplans
- Additional thermal loading from electrical lights

Basic Dimensions:

- Height: 325 ft (22 floors)
- Footprint: 131.75' x 99.25' ~ 12,965 SF
- Curtain / Window: 12' x 7' = 84 SF
- Window layout and footprint are symmetric



IMPORTANCE OF IEQ FROM A FACILITY PERSPECTIVE

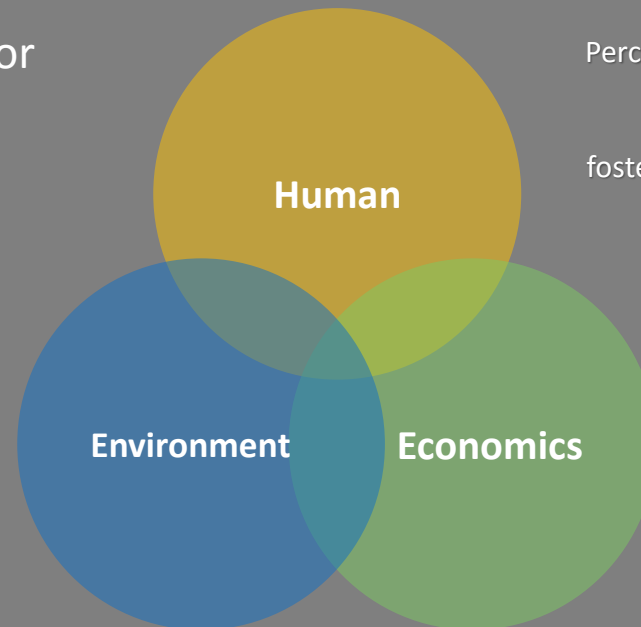


- 1 window: 3,800 BTU/SF @ 84 SF / window ~ **~319,200 BTU / window**
- 1 space heater: ~ 5120 BTU
- 1 window ~ **62 space heaters (peak)**
- Result: huge solar gains in summer => increased demand for cooling

OBJECTIVES ADDRESS ENGINEERING AND PSYCHOLOGY

- Quantify margin of improvement in floor's **energy performance** (\$ / env)
 - Estimate ROI and influencing factors
 - Identify barriers to implementation
- Improve **occupant satisfaction**, reduce **operation effort** (people)
 - Identify primary factors influencing occupant satisfaction (and productivity)
 - Identify primary factor influencing maintenance procedures
- Inform lighting retrofit / commissioning **best practices** (knowledge)
 - Assess experiment economics and utility
 - Identify indicators of improvement to continuously monitor
 - Provide practice-ready recommendation

IMPACTS:
Emissions resulting from
energy production /
consumption



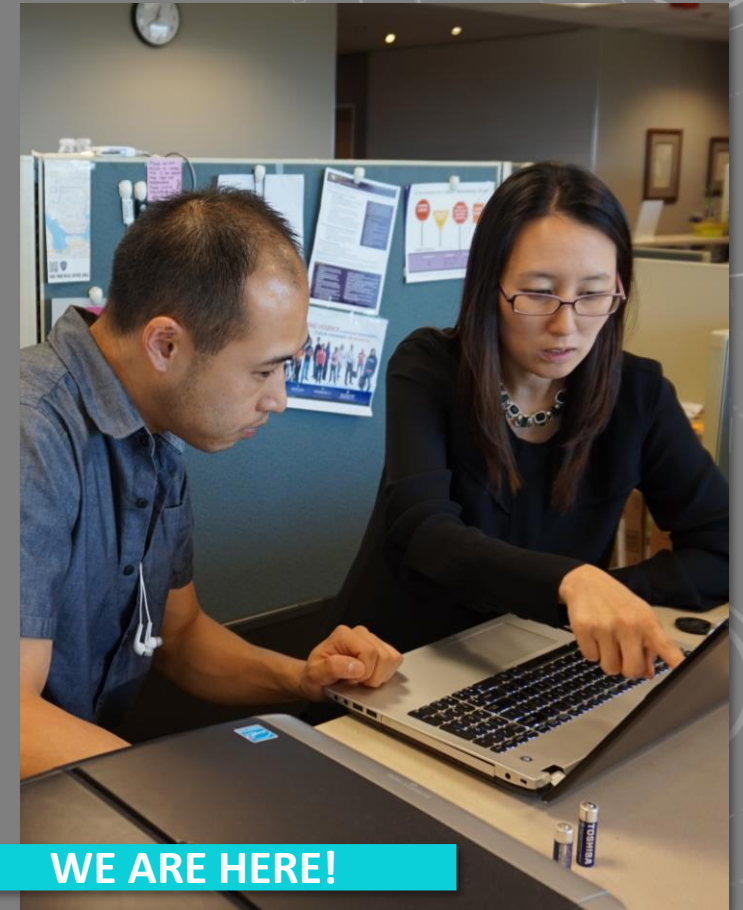
IMPACTS:
Perception, health, and comfort
impact well-being and
productivity,
fosters branding and reputation

IMPACTS:
Energy consumption,
occupant productivity, life-
cycle costs, property value

PROJECT SCHEDULE HAS EVOLVED OVER TIME

Task	Task Description	Q1	Q2	Q3	Q4	Q5
Task 1	Kickoff meeting	✘				
Task 2	Develop survey tool		✘			
Task 3	Submit HSD Application	✘	✘			
Task 4	Study specifications and scope		✘		★	
Task 5	Define lighting study design		✘			
Task 6	Spot data monitoring		✘	✘	✘	
Task 7	Data visualization		✘	✘	★	
Task 8	Pre-retrofit survey & analysis		✘		✘	
Task 9	Install lighting upgrades			✘		
Task 10	Lighting control system			✘	✘	
Task 11	Final report			✘	★	●
Task 12	Post-retrofit survey & analysis				★	●
Task 13	Focus Interviews				★	●
Task 14	Fine-tune Lighting Controls				★	●

LEGEND: ✘ Completed ★ In Progress ● To Be Completed



WE ARE HERE!

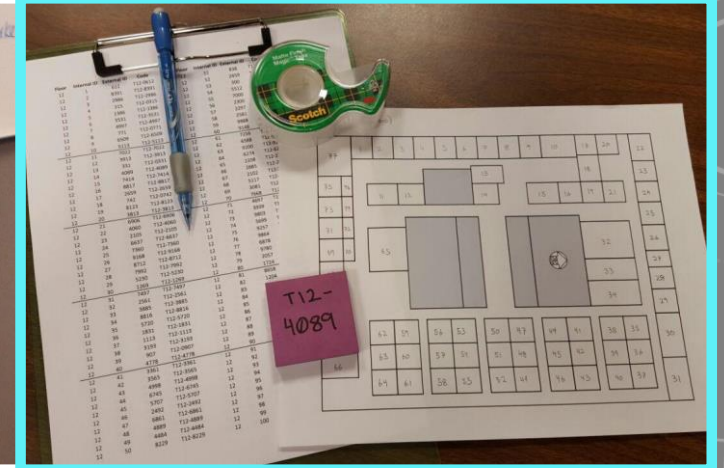
A YEAR-LONG PROJECT STILL IN PROGRESS



Spot Measurements...



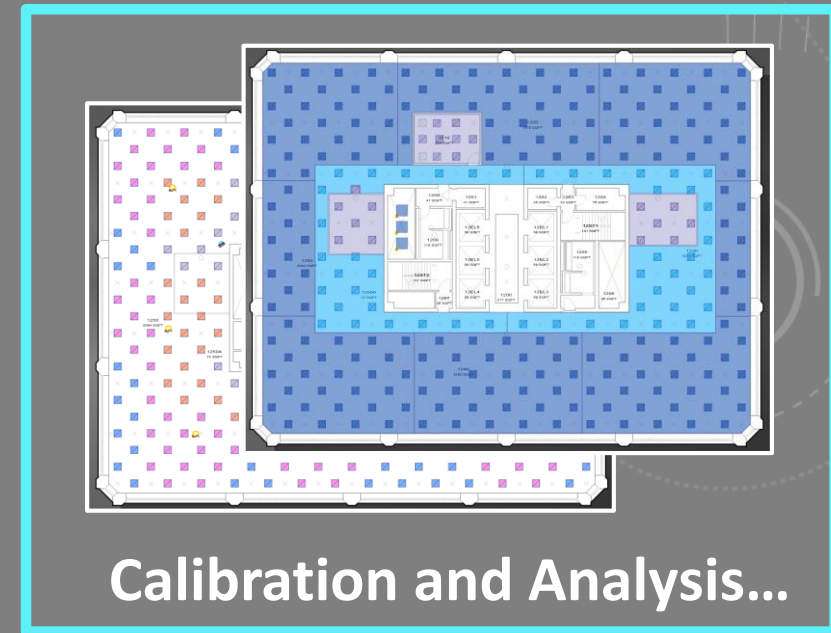
Continuous Monitoring...



Occupant Surveys...

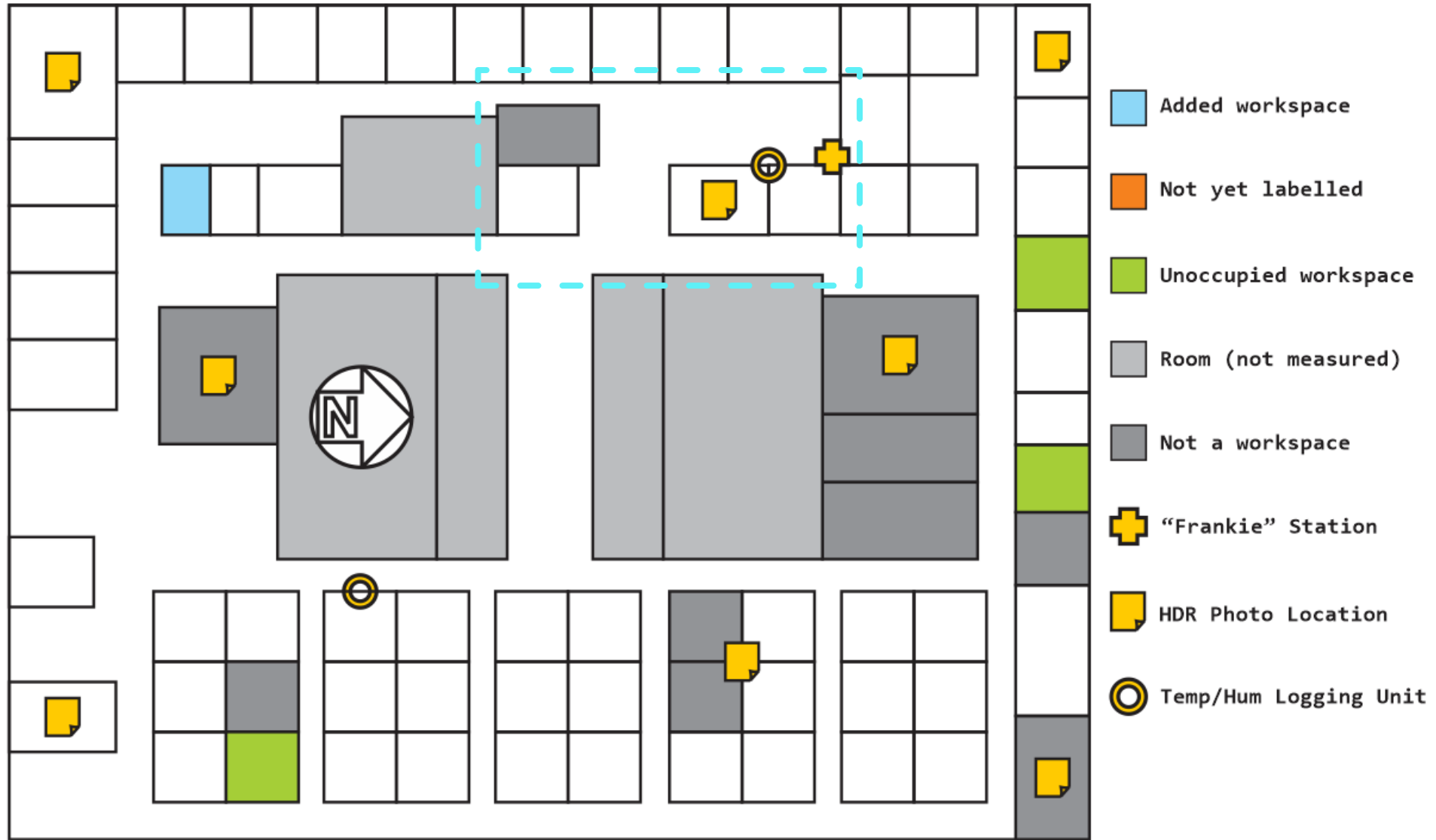


Fixture Retrofits and Lighting Controls Commissioning...



Calibration and Analysis...

DATA COLLECTION POINTS PLANNED IN ADVANCE



"Frankie" Station

CONTROLS AND APPEARANCE HAVE CHANGED

Installed December 2015 / January 2016

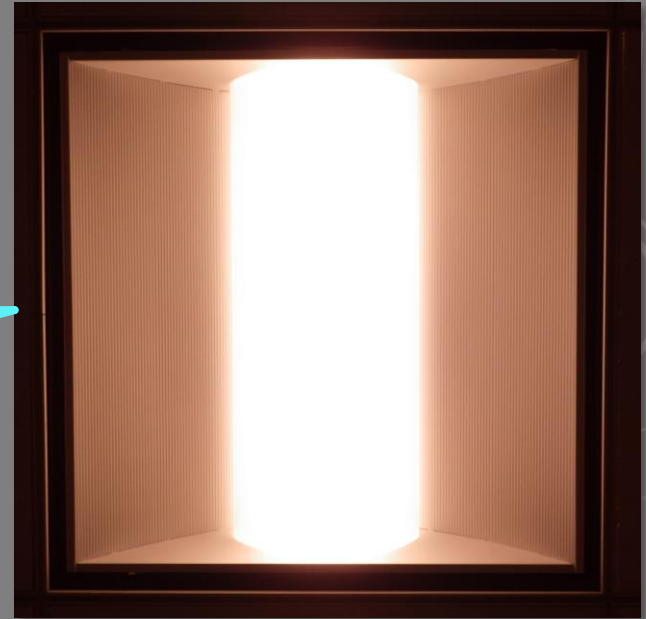
- LED fixtures with rated warmer color rating, less direct glare
- Wi-Fi controlled fixtures via terminal
- Daylight harvesting (photometric sensors)
- Custom zone definitions and scheduling rules
- Real-time Monitoring and performance visualizations
- Expansion modularity and reporting capabilities



OLD FIXTURE

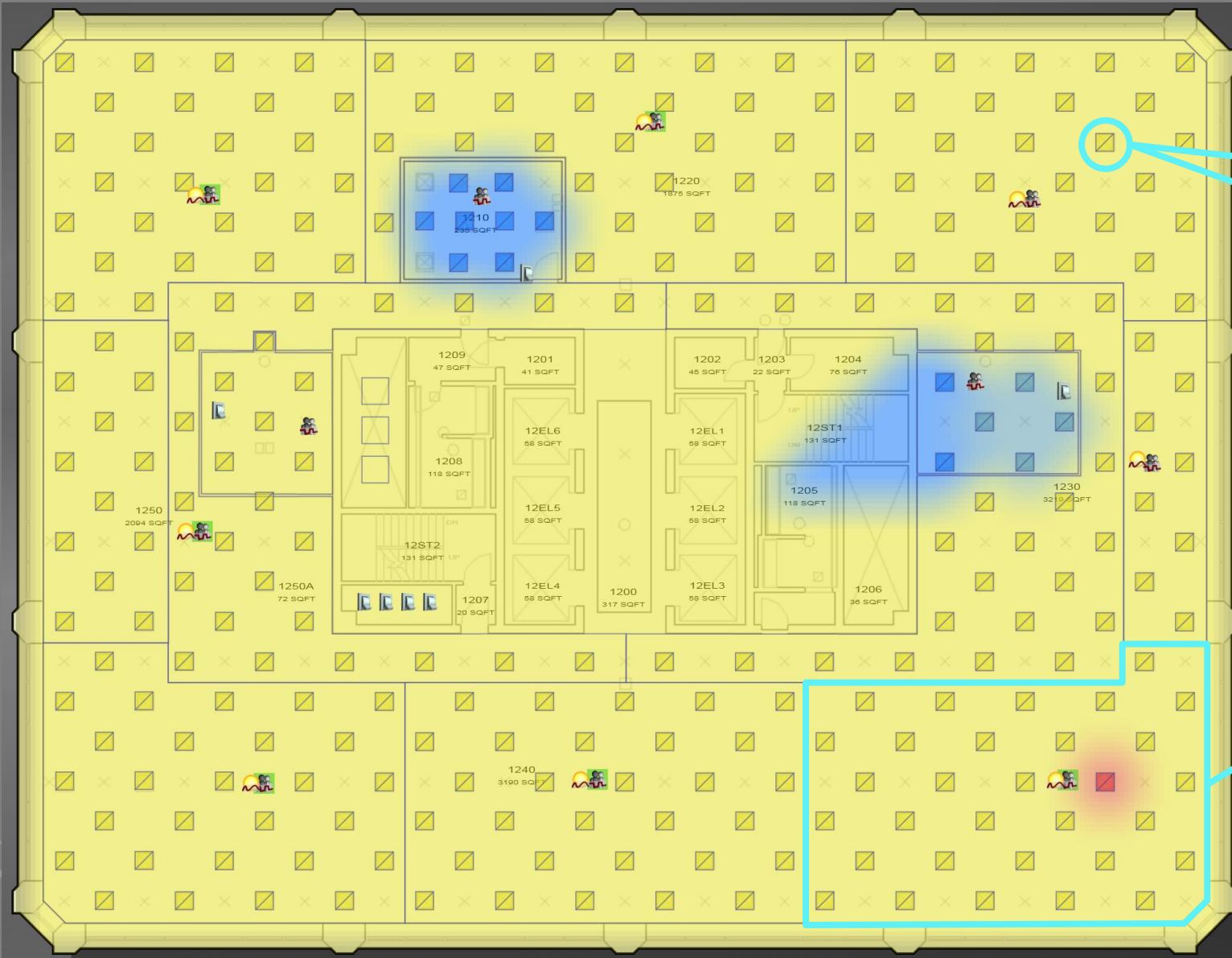


December 2015, 12th Floor of UW Tower



NEW FIXTURE

CONTROL, MODULARITY, AND REPORTING



Behavior

Template 2x2

Rotation Angle 0 Degrees

Burn-In Duration 0 h

Startup behavior Default

Brightness Level

Max Brightness 50 %

Off State Brightness 0 %

Comfort Brightness Type Absol

Comfort Brightness 15 %











Min Comfort Brightness 0 %

Forced Override Brightness 100 %



80% WOULD PREFER AT LEAST 1 CHANGE



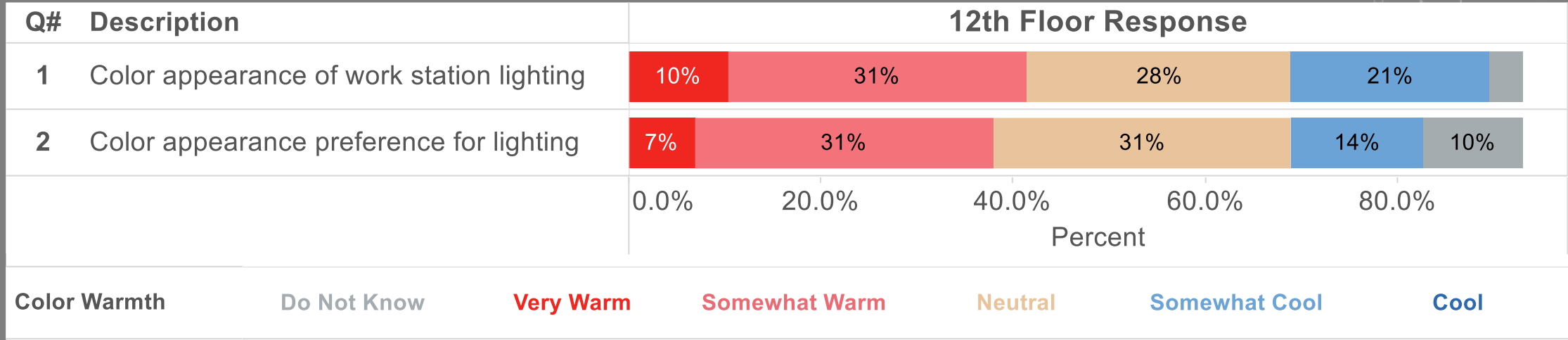
Preference	12th Floor (N = 40)	15th Floor (N = 18)	Both Floors (N = 58)
Change the color appearance of the light produced by the lighting fixtures	42.5% 	33.3% 	39.7% 
Be able to control the brightness/light output of the overhead lighting fixtures with a dimmer or high/low switch	40.0% 	50.0% 	43.1% 
Make the overhead lighting fixtures produce less glare	35.0% 	27.8%	32.8% 
Change the aesthetic appearance of the light fixtures	27.5%	38.9% 	31.0%
Add a task light	20.0%	33.3% 	24.1%

Prior to Retrofits...

- About 20% would not change anything
- Above all, occupants value the *capacity to control*
- Occupants may prefer different colors depending on time of day
- 70% of 12th floor indicated not having a task light (50% for 15th floor)
- Should task lighting be used to achieve what overhead fixtures cannot?

LIGHT ZONES HAVE DISTINCT PREFERENCES

Aggregated data doesn't distinguish zonal responses...



SW	W	NW
S	Zone	N
SE	E	NE

5	9	6
3	Data Pts	1
3	7	6

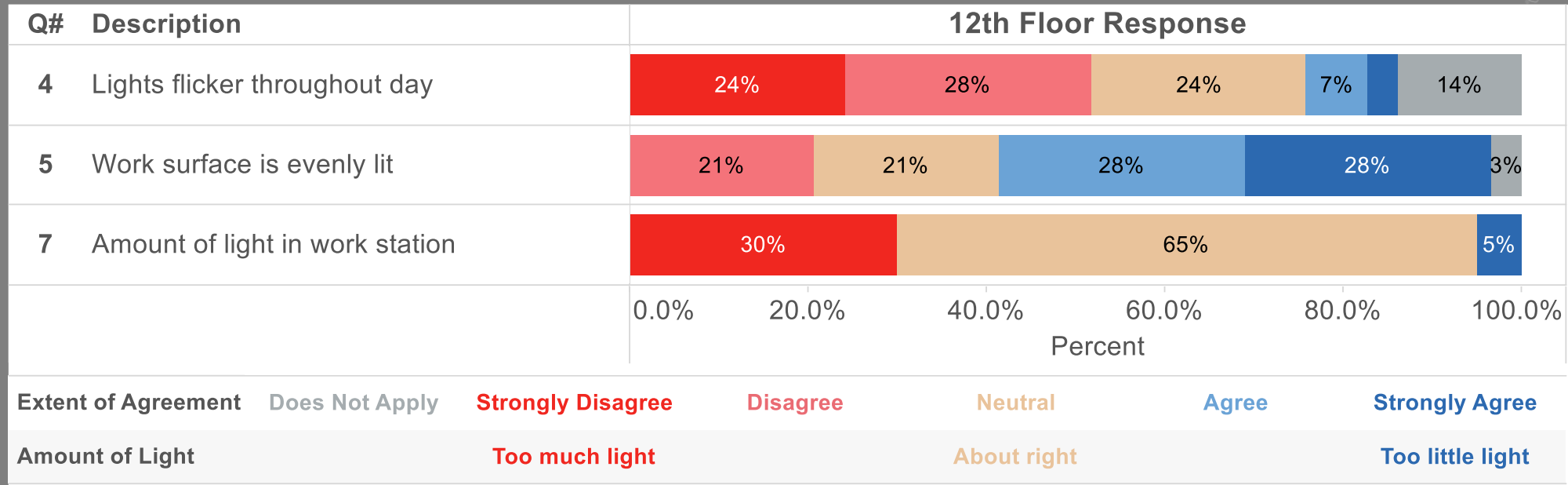
...but grouping data by lighting zone reveals distinct zonal preferences

0.2	-0.3	-0.2
-0.3		-1.0
0.3	0.4	-0.5

-1 = average zone occupant wants **warmer** colored lights

+1 = average zone occupant wants **cooler** colored light

ZONES GENERALLY AGREE: TOO MUCH LIGHT



Lights flicker throughout day?

1.8	2.2	2.7
3.0		2.0
2.7	2.1	2.5

1 = strongly disagree
3 = neutral
5 = strongly agree

Work surface evenly lit?

3.8	3.2	3.2
3.3		4.0
3.7	3.4	3.3

1 = strongly disagree
3 = neutral
5 = strongly agree

Amount of light in work station?

3.4	3.4	3.0
3.7		3.0
3.7	3.6	3.7

1 = too little light
3 = neutral
5 = too much light

HEAT MAPS VISUALLY CONVEY PERFORMANCE LEVELS

IESNA Recommended Minimum Illuminance Table

Red = closed blinds



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29		
A	1500	1676	3400			1069	2000				1300	804								690	1600	787					2000	1157	1300	A	
B	1900	1800	2083			1200	1600				1200	1100								450	930	740					1650	1300	1300	B	
C	2400	1750	1050																				840	720						C	
D																							720	600							D
E					900	713	600							330	260	420	500					600	510					1400	600	E	
F					770	640	620							400	387	500	500					510	420					2200	1400	F	
G																														G	
H	1225	830	730																											H	
I	1620	1128	630																												I
J	2163	1430	1040																												J
K	3440	1977	1060																												K
L																												1400		L	
M																												850		M	
N																											300			N	
O																														O	
P																														P	
Q					700	545					520	480								620	580	600				590	635			Q	
R					640	390					590	440	570							660	648	620				597	680			R	
S	3540	2237	1180		830	733					810	750	700							713	730	680				520	623			S	
T	2680	1990	1687		1037	980					882	1050	990							750	745	690				563	670	1000	1150	T	
U	2510	2063	1890		1300	1140					786	1019	1220							780	810	750				500	585	1033	1300	U	
V	1457	1860	1251																								800	710		V	

Amount of light in work station?

3.4	3.4	3.0
3.7		3.0
3.7	3.6	3.7

W
S N
E

POST-RETROFIT BRIGHTNESS LEVELS ARE LOWER

IESNA Recommended Minimum Illuminance Table

Red = closed blinds



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
A	1240	914	1440			619	450				2400	1304							1580	923	1050	554					1320	1021	1370	A
B	1218	975	1035			1400	925				1950	1500							1310	1040	893	590					1343	1365	1368	B
C	1440	1035	690																					310	380					C
D														240	280									380	450					D
E					560	443	450	357	280					277	320							250	275					1183	1360	E
F					440	320	370	340	310					270	295							275	300					1005	1183	F
G																														G
H	452	379	370																											H
I	525	756	360																											I
J	1478	1760	897																											J
K	2150	1470	570																											K
L	1505	1400	923																									490	695	L
M	965	981	800																									710	900	M
N	863	760	780																									740	820	N
O																														O
P																														P
Q					360	390					305	348	430						430	400	325				400	383			Q	
R					374	420					315	310	418						460	410	250				375	365			R	
S	3540	1830	920		343	491					330	466	515					599	530	457				360	338			S		
T	1957	1030	1050		521	710					563	710	648					808	652	590				340	290		770	1100	T	
U	1300	1226	1200		510	610					650	693	720					744	680	635				370	330		1178	1430	U	
V	892	1375	859																									1335	931	V

Amount of light in work station?

3.4	3.4	3.0
3.7		3.0
3.7	3.6	3.7

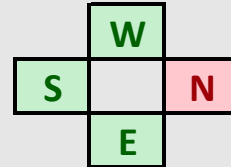
DIFFERENCES IN MEASUREMENTS: LOWER BRIGHTNESS LEVELS

Blue = Post-Retrofit measurement is dimmer

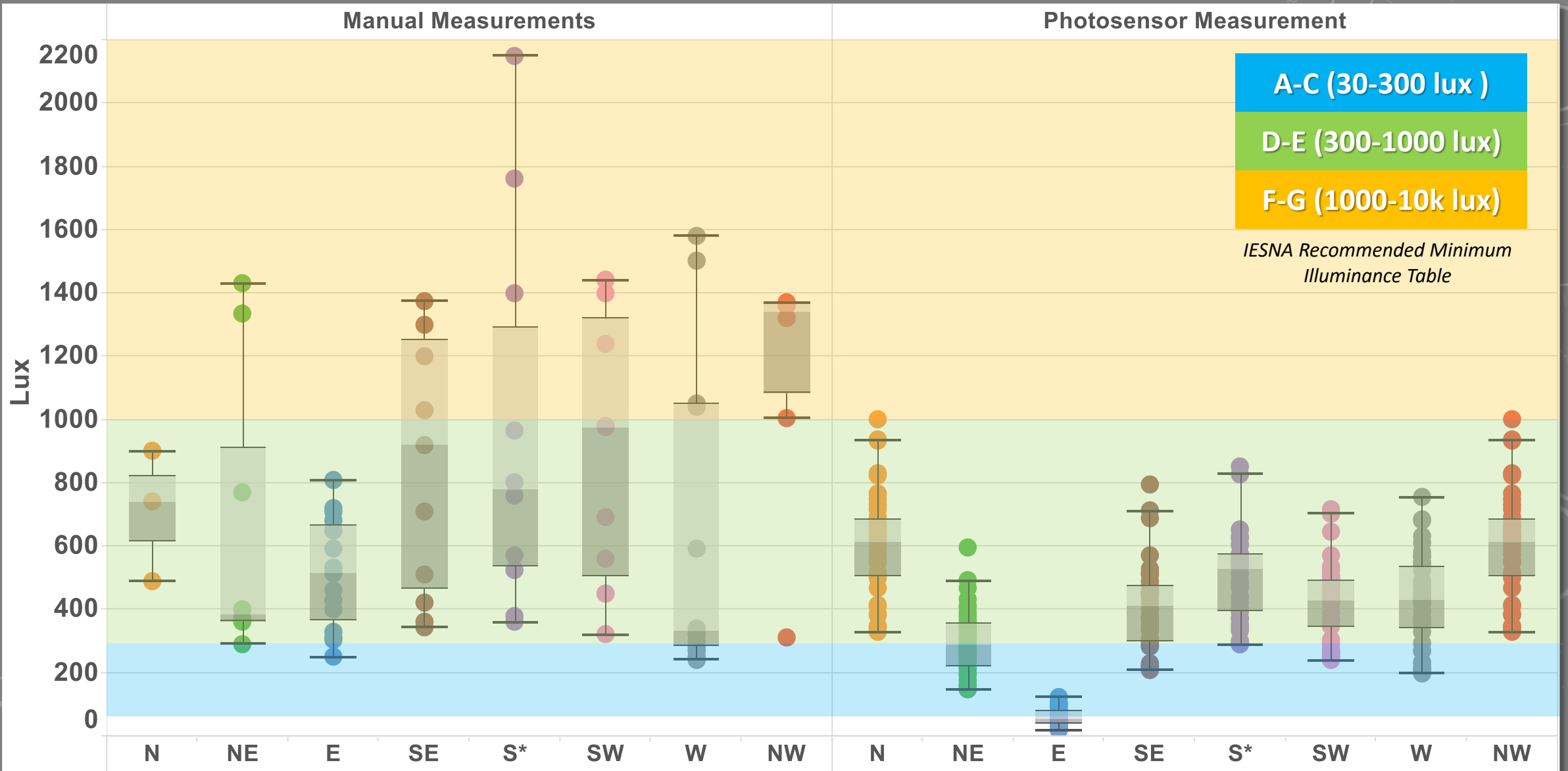
Red = Post-Retrofit measurement is brighter

White = No change

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29		
A	260	761	1960			450	1550				-1100	-500									-233	170	233				680	136	-70	A	
B	682	825	1048			-200	675				-750	-400										-590	37	150			308	-65	-68	B	
C	960	715	360																				530	340						C	
D																							340	150						D	
E					340	270	150								53	-60							350	235				218	-760	E	
F					330	320	250								130	92							235	120				1195	218	F	
G																														G	
H	773	451	361																											H	
I	1095	372	270																											I	
J	685	-330	143																											J	
K	1290	507	490																											K	
L																												910		L	
M																												140		M	
N																												-440		N	
O																														O	
P																														P	
Q					340	155					215	132										190	180	275			190	253	Q		
R					266	-30					275	130	152									200	238	370			222	315	R		
S					487	242					480	284	185									114	200	223			160	285	S		
T	723	960	637		516	270					319	340	342									-58	93	100			223	380	230	50	T
U	1210	836	690		790	530					136	325	500									36	130	115			130	255	-145	-130	U
V	565	485	392																									-535	-222	V	



SENSORS DON'T DETECT EVERYTHING



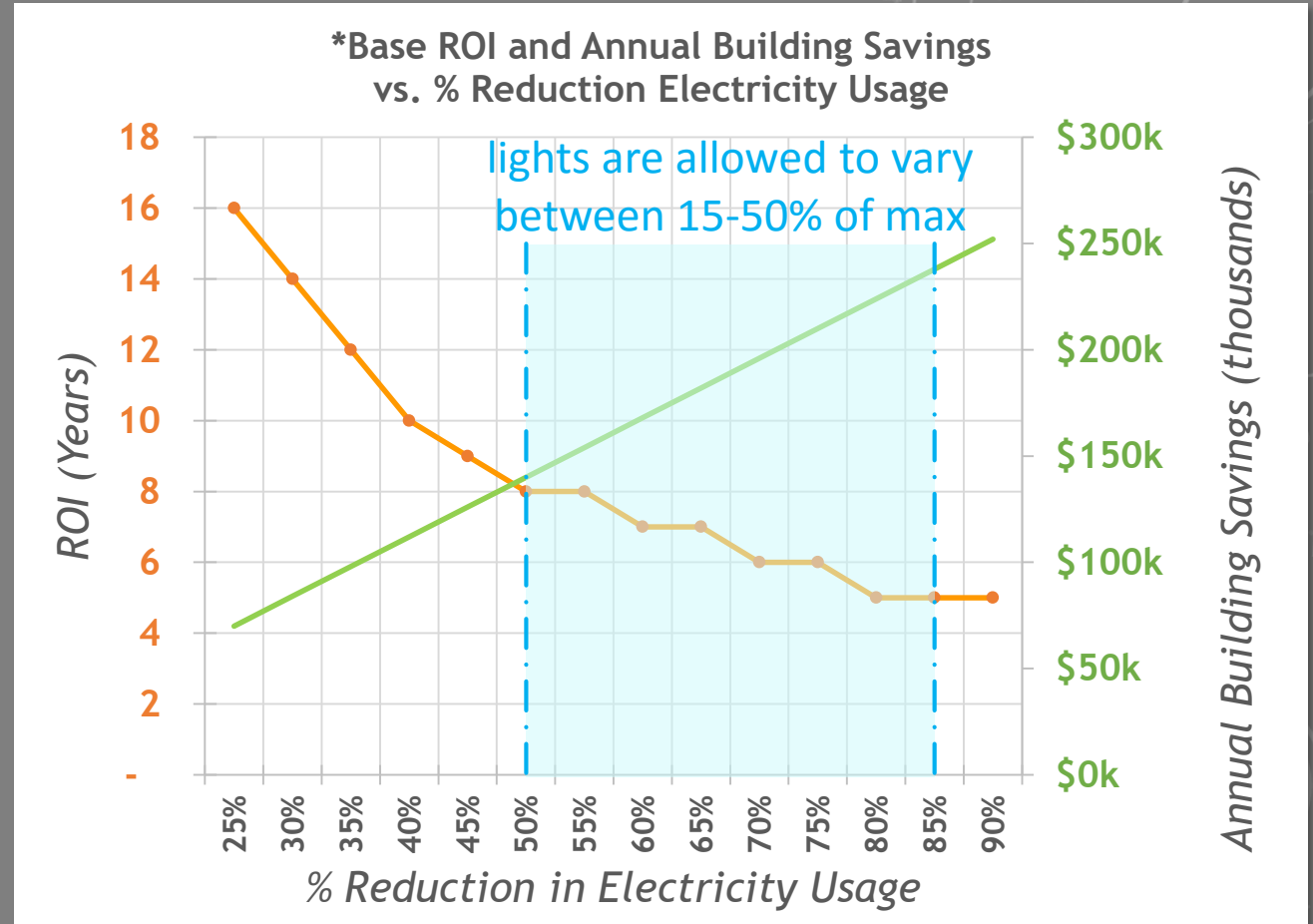
* 2 data points removed as outliers

ROI DEPENDS ON REDUCTION IN ELECTRICITY USAGE

Assumptions:

- \$1 million total energy costs for building
- ~ \$50k / yr / floor x 20 floors
- ~35% energy usage for lighting fixtures
- \$17.5k / yr / floor for lighting
- ~\$85 / fixture alone, \$200 including control
- ~\$70k / floor x 16 floors

~\$1.12 million to perform
lighting retrofit entire UW Tower



***Calculation excludes additional factors which would reduce the ROI**

TECHNOLOGY SHOULD ENABLE OCCUPANTS TO DO MORE

To be truly useful, technology should enable facility staff to do more. Occupant behavior, perception, and health particularly matter because their needs are addressed by facility staff.

Key Recommendations

- Minimize time between fixture installation and controls commissioning
- Involve occupants in the choice of installation dates, lighting fixture choice
- Develop strategy for periodic recalibration
- Use reporting / monitoring features to develop performance benchmarks



ACKNOWLEDGEMENTS

a special thanks to occupants of 12th and 15th floor for their patience and engagement throughout the process

UW Tower Facilities and Operations Staff

UW Green Seed Fund

Environmental Stewardship Committee Members

Norm Menter, UW Tower Facility Services

Encelium Staff

Lindsay McCunn, Assistant Professor at UW Tacoma

Nick Yasinski, Biostatistics (15th floor)

Thomas Cheong, undergraduate researcher

Michael Stolp-Smith, HDR photographer and alumni



QUESTIONS, COMMENTS?

THANKS FOR LISTENING!



EXTRA SLIDE INDEX

IESNA RECOMMENDED MINIMUM ILLUMINANCE



MCKINSTRY DASHBOARD: HISTORICAL PERFORMANCE



MCKINSTRY DASHBOARD: AVERAGE PERFORMANCE



12TH AND 15TH FLOOR LIGHTING PLANS



WORKSPACES AND EQUIPMENT MAPS



STATIONARY MEASURING EQUIPMENT



RECOMMENDED MINIMUM ILLUMINANCE TABLE



Category	Description	Recommended Min. Illuminance Level
A	Public spaces	30 lx
B	Simple orientation for short visits	50 lx
C	Working spaces where simple visual tasks are performed	100 lx
D	Performance of visual tasks of high contrast and large size	300 lx
E	Performance of visual tasks of high contrast + small size, or low contrast + large size	500 lx
F	Performance of tasks of low contrast and small size	1000 lx
G	Performance of visual tasks near threshold	3000 - 10,000 lx

From IESNA Lighting – Ready Reference (4th Edition)

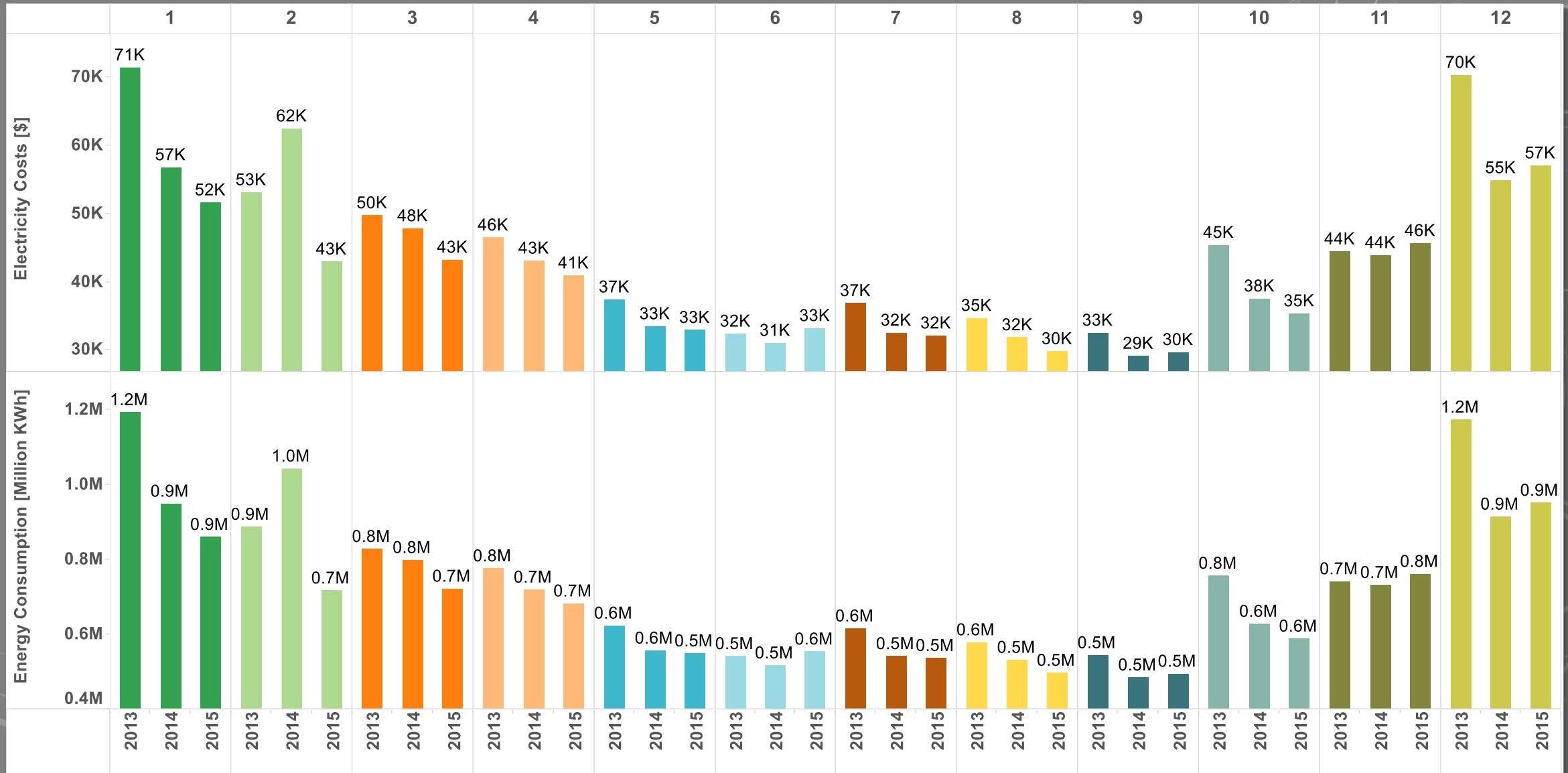
A-C (30-300 lux)

D-E (300-1000 lux)

F-G (1000-10k lux)

Extreme (10,000+ lux)

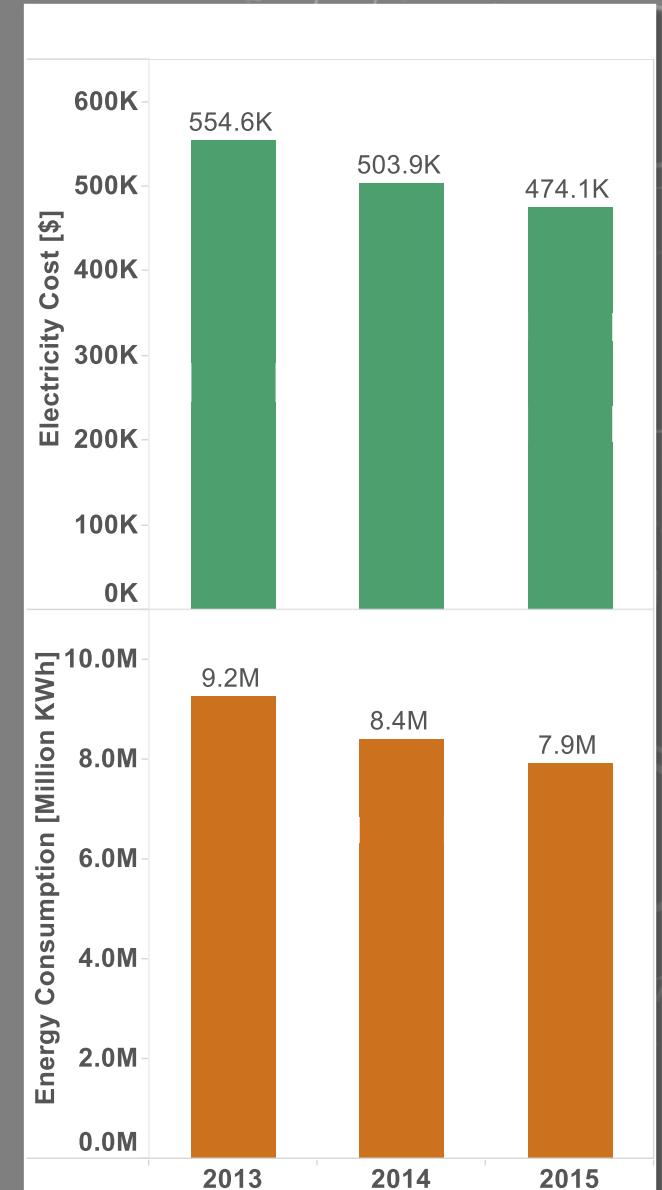
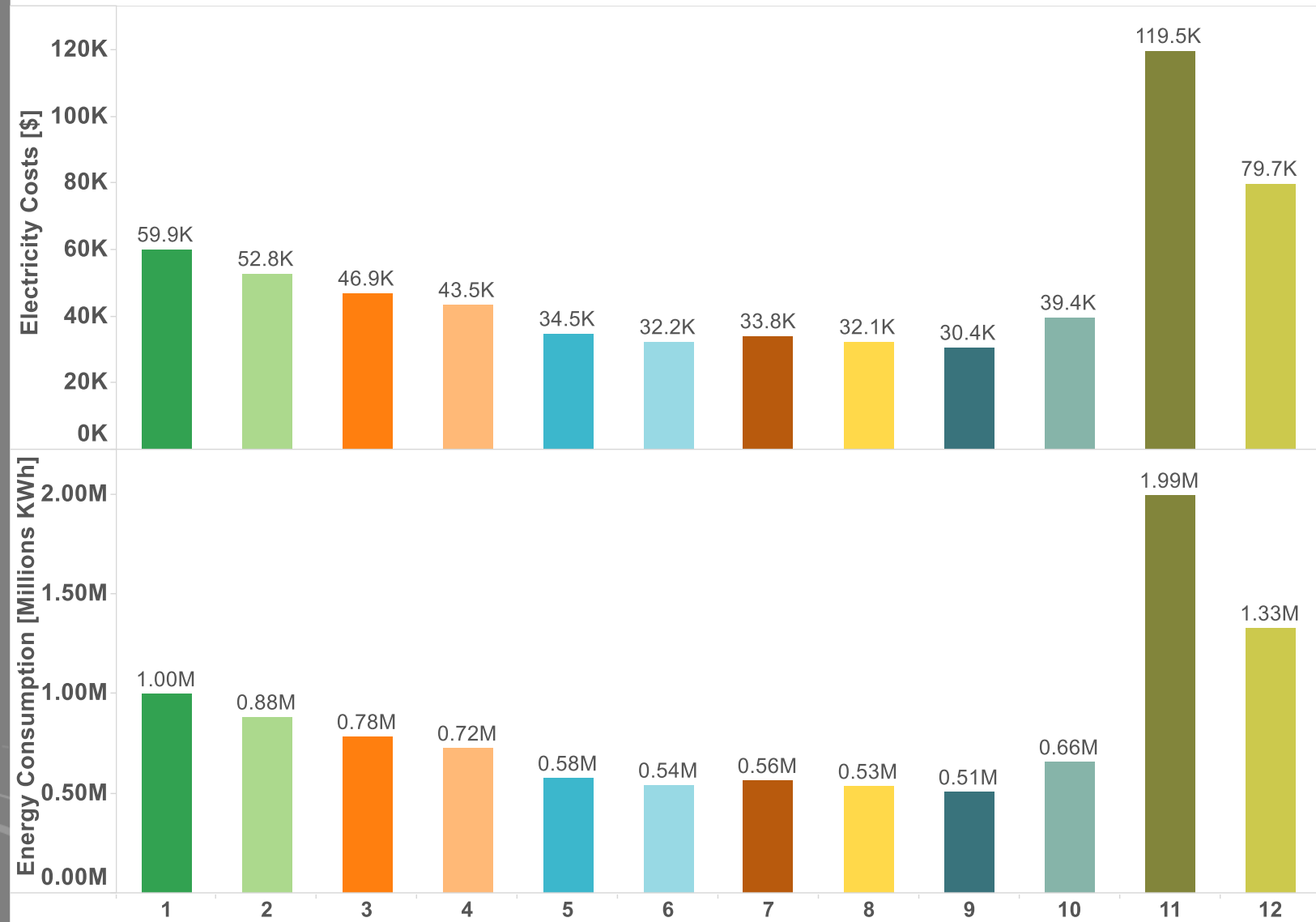
IMPORTANCE OF IEQ FROM A FACILITY PERSPECTIVE



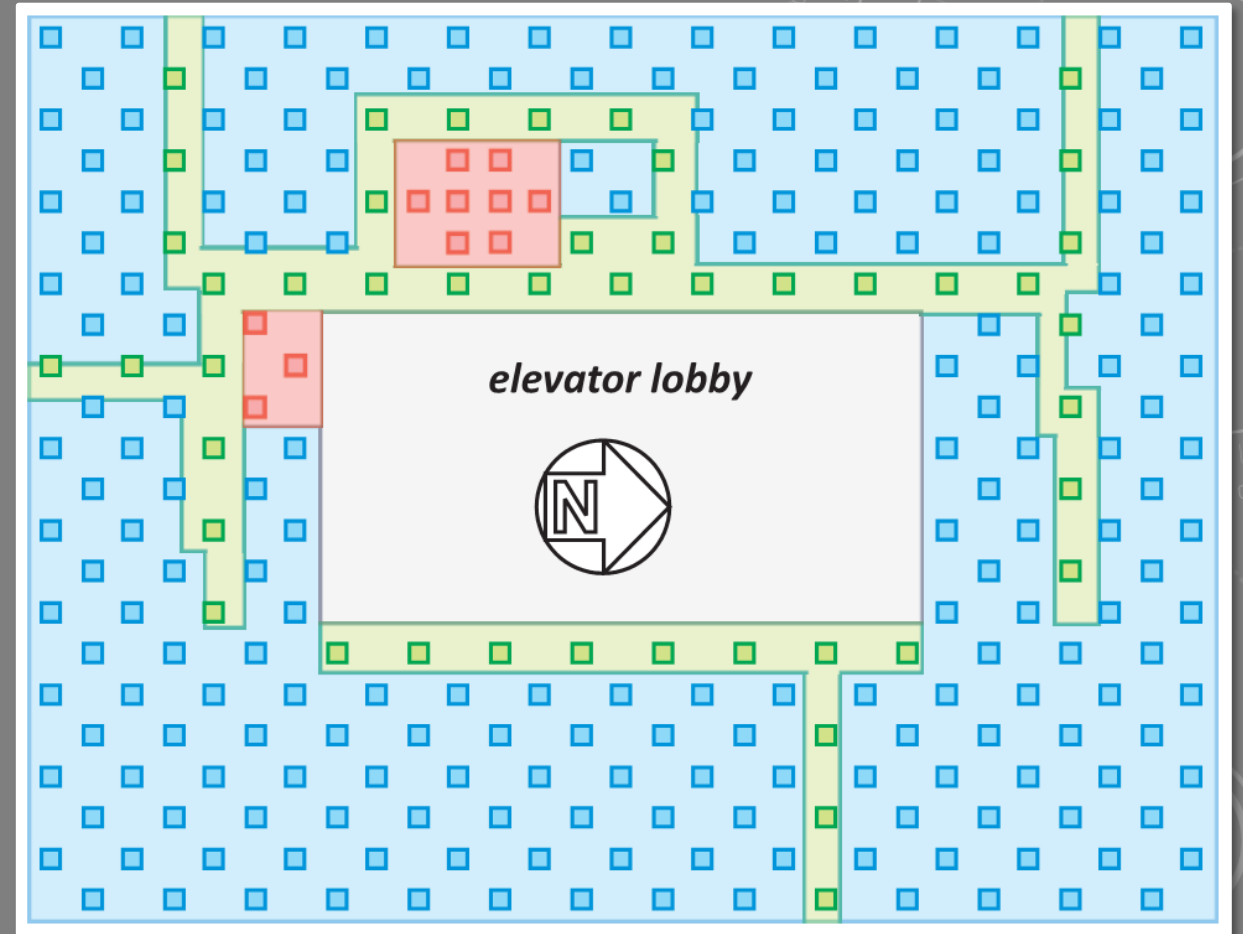
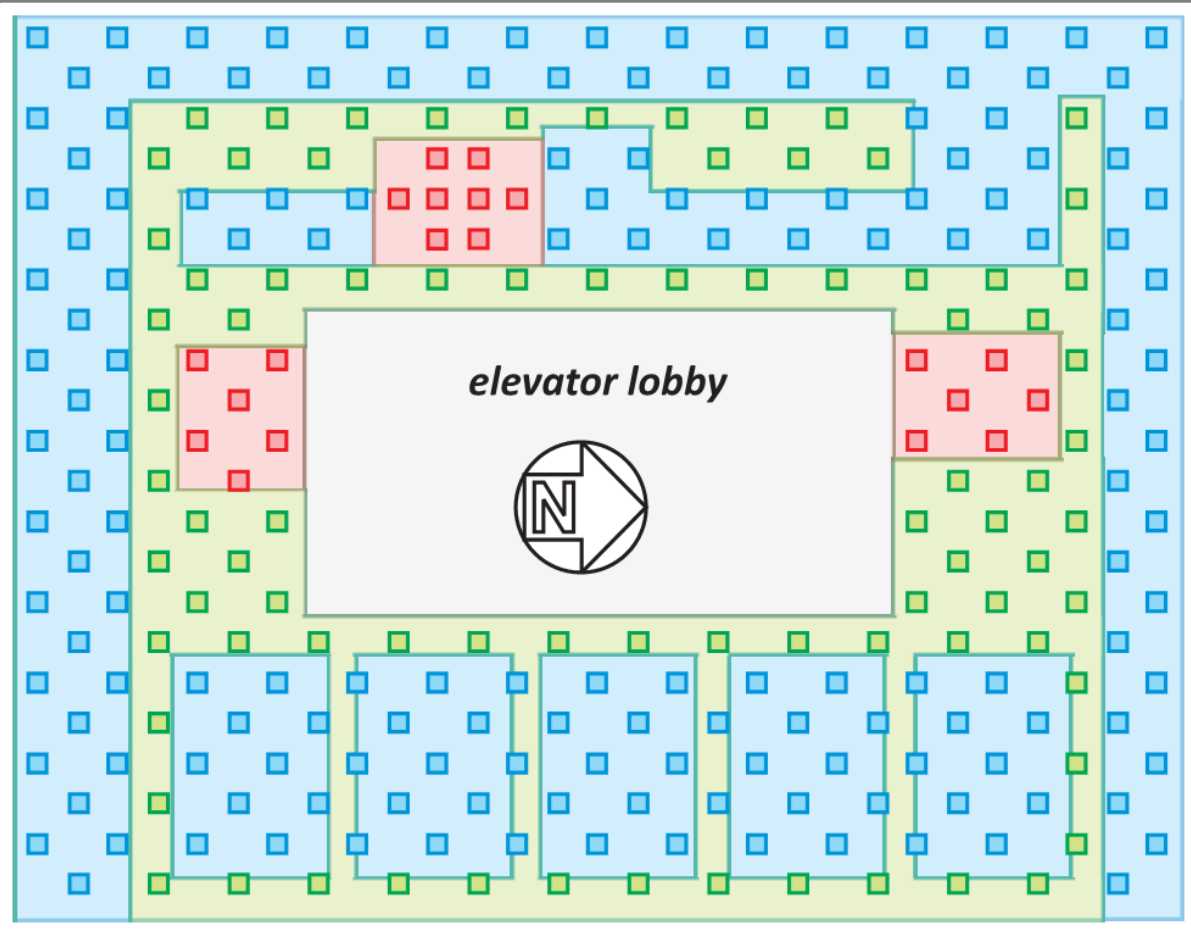
IMPORTANCE OF IEQ FROM A FACILITY PERSPECTIVE



Average Monthly and Annual Electricity Costs and Consumption



SPACE CATEGORIZATION

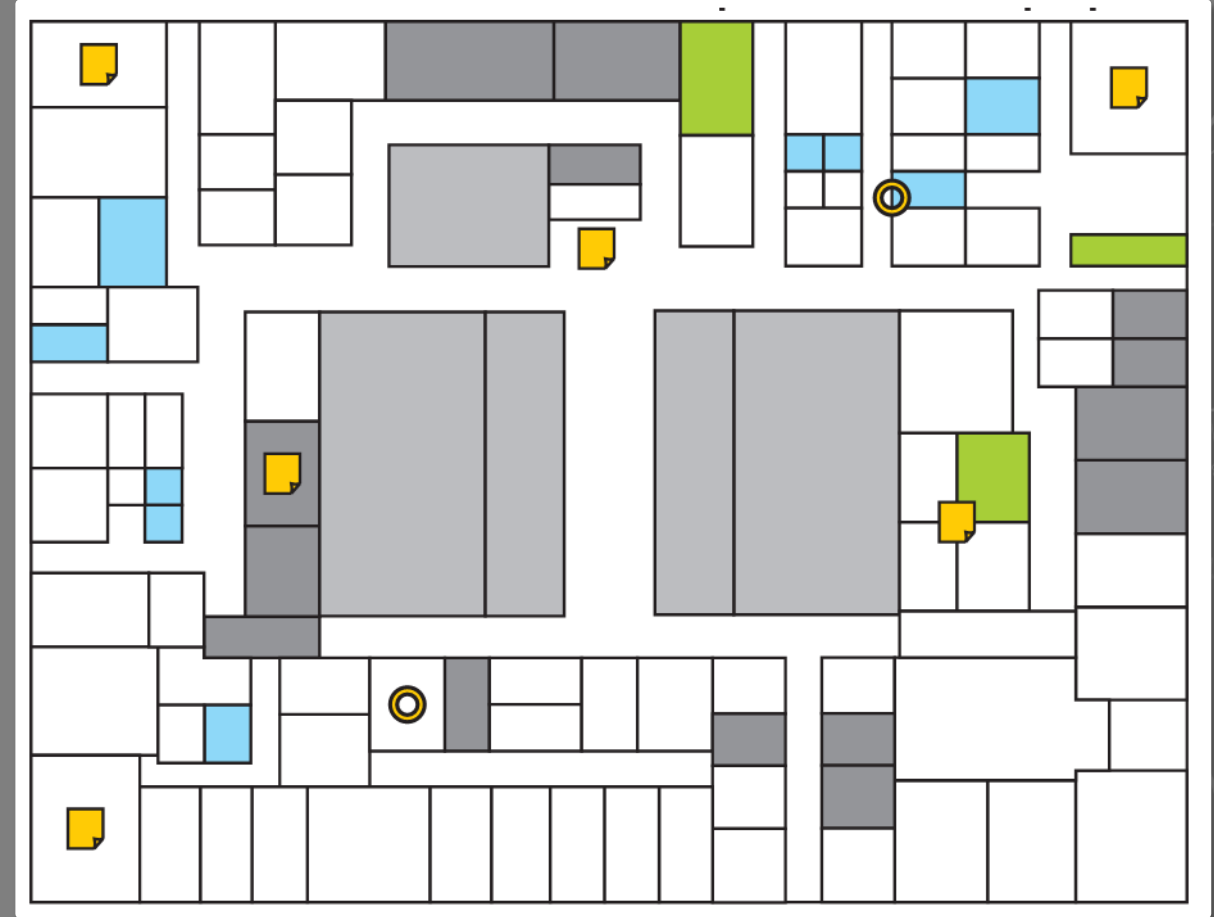
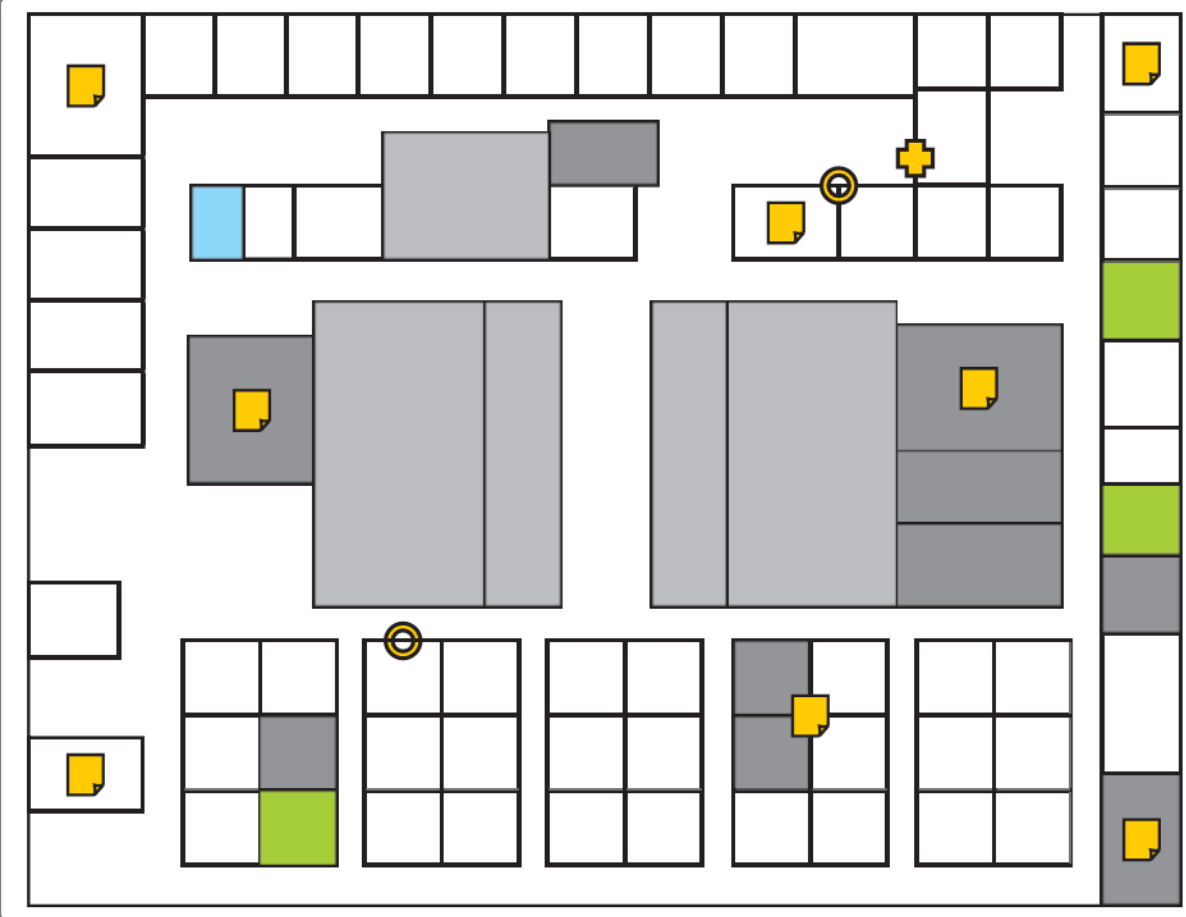


12th Floor

 Workspace / Desk  Enclosed Room  Walkway / Floorspace









15th Floor

WORKSPACES AND EQUIPMENT MAP



12th Floor

15th Floor

 Added workspace	 Not a workspace	 HDR Photo Location
 Not yet labelled	 Room (not measured)	 Temp/Hum Logging Unit
 Unoccupied workspace		 "Frankie" Equipment Station

STATIONARY MEASURING EQUIPMENT (FRANKIE)



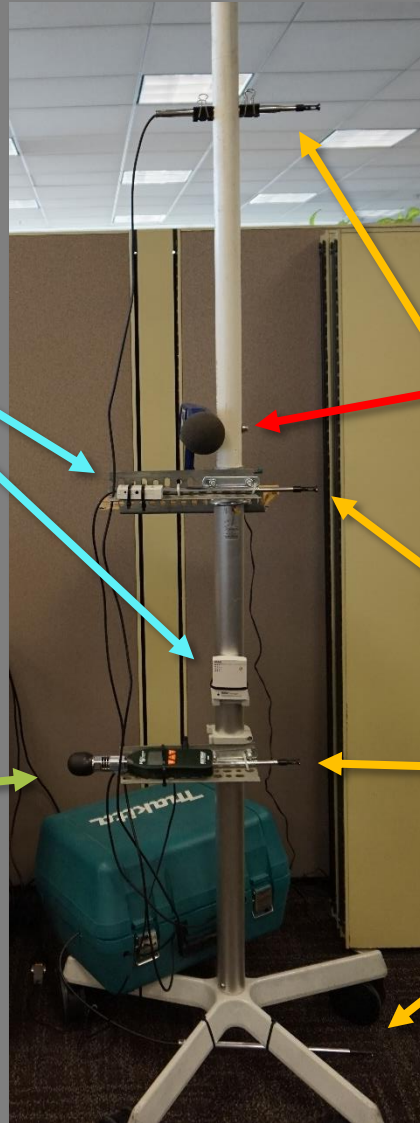
Temperature +
Relative Humidity

x1



Temperature,
RH, Light

x2

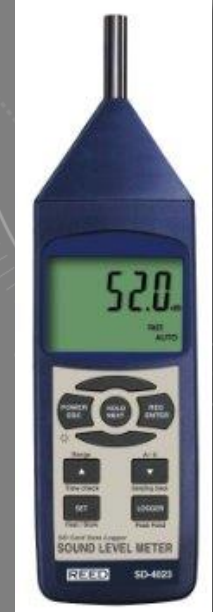


“Frankie”



Temperature,
Air velocity

x4



Sound Levels

x1

TECHNOLOGY SHOULD ENABLE OCCUPANTS TO DO MORE



Questions to be answered

- To what extent should occupants have control over the lighting fixtures?
- What reporting and monitoring features are most useful to facilities O&M?
- What strategies will further reduce the ROI?
- To what extent can the technology achieve occupant satisfaction?

Lessons Learned

- Lighting fixture = largest contributor to economic / energy savings
- Lighting controls key to occupant satisfaction + productivity (including mgmt.)
- New fixtures produce less light, seemingly reduce brightness gradients ('caves')
- Occupants value changes that improve their an ability control their lighting quality
- Each floor requires slightly different designs due to unique floor plans + occupant tasks
- Retrofitting / commissioning process can potentially create an extended, disruptive interim period
- Manual equipment can detect things the light sensors cannot