



# Indoor Environmental Quality and HVAC Survey of Small and Medium Size Commercial Buildings: Phase I

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# Acknowledgements



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# Summary and Importance



- **Small and medium-sized commercial buildings (SMCBs)**
- **~96% of Commercial Buildings are <math><50,000\text{ ft}^2</math>**
- **~10% of US Commercial Buildings in California**
- **Almost no information on SMCB operation, maintenance, condition, HVAC systems, etc.**
- **SMCBs an important part of building sector, influences energy use, human comfort, health, and productivity.**
- **SMCB construction, operation and maintenance of interest to CEC from policy perspective: Title 24**



# SMCB Definition This Study

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- **Constructed after 1978**
- **Floor area between 1,000 and 50,000 ft<sup>2</sup>  
(93m<sup>2</sup> - 4650m<sup>2</sup>)**
- **Fewer than four stories**
- **Roof-top ventilation and air conditioning**



# Phase 1 Objectives



## Phase 1: Telephone Survey to SMCBs

- Develop statewide survey information on:
  - ventilation characteristics of SMCBs
  - The operation and maintenance characteristics of SMCBs
  - basic construction details of SMCBs
- Obtain statewide survey data on indoor air quality (IAQ) characteristics
- Characterize remedial actions in response to IAQ issues
- Assess correlation of building/equipment characteristics with potential for poor ventilation and IAQ
- Obtain data to identify frequency distribution of:
  - various building use types
  - indoor occupancy
  - source types
  - ventilation types
- Recruit study Buildings for SMCB Phase 2 Project



# Recruitment



- **Challenges:**

- Locate CA SMCBs built 1978 on
- Obtain complex set of building information
  - Identify key contacts with knowledge of physical plant, operations, maintenance, etc.

- **Sample Frames**

- DataQuick (building database)
  - Poor access to owners
- Dun & Bradstreet (D&B, business database)
  - Time consuming, but contacts accessible



# Survey Strategy



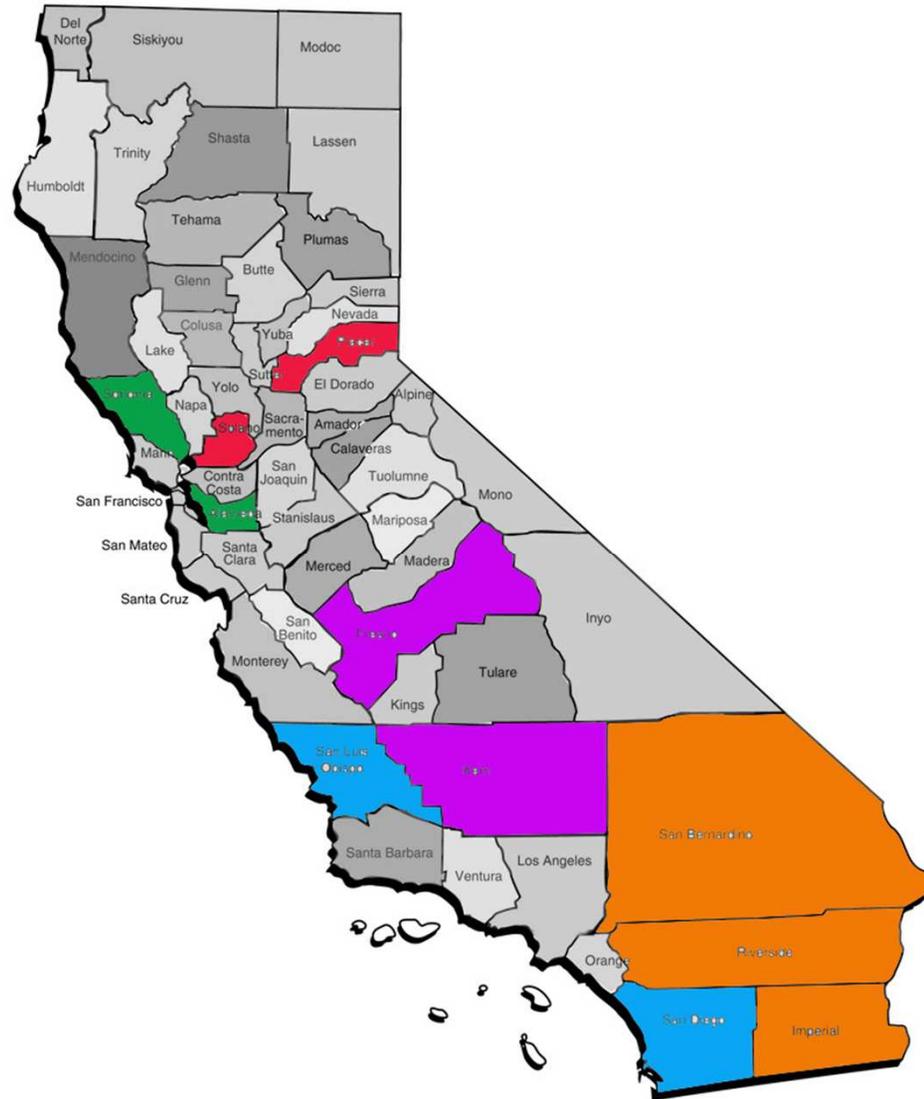
- **Survey using D&B database**
  - Telephone Survey
  - D&B has no building age data
  - Necessary to increase probability of reaching newer buildings
    - Selected fastest growing CA counties
  - Difficulty obtaining HVAC characteristics on phone
    - Mailback supplementary HVAC equipment survey



# Counties Surveyed



- Coast – North
  - Alameda
  - Sonoma
- Inland – North
  - Placer
  - Solano
- Inland – Central
  - Fresno
  - Kern
- Coast – South
  - San Luis Obispo
  - San Diego
- Inland – South
  - Riverside
  - San Bernardino
  - Imperial





# Survey Statistics by Region and Size



**Table 4. Distribution of Sample by Region and Size Strata**

Region / Size	Put into field	Eligible	Completed
<b>1. Coast-South / Small</b>	312	115	21
<b>Medium</b>	312	123	47
<b>Large</b>	156	40	15
<b>2. Coast-North / Small</b>	396	100	32
<b>Medium</b>	330	95	38
<b>Large</b>	99	22	10
<b>3. Inland-South / Small</b>	354	112	33
<b>Medium</b>	312	119	56
<b>Large</b>	114	33	13
<b>4. Inland-Central / Small</b>	405	148	50
<b>Medium</b>	312	130	53
<b>Large</b>	63	17	7
<b>5. Inland-North / Small</b>	608	215	62
<b>Medium</b>	189	78	35
<b>Large</b>	24	6	4
<b>TOTAL</b>	<b>3,986</b>	<b>1,353</b>	<b>476</b>



# HVAC Survey



- **A supplementary HVAC Survey was mailed out to willing participants.**
- **Focus on:**
  - Equipment
  - Maintenance
  - Filtrations
  - Setpoints
  - Schedules
  - Ventilation settings
- **71 Completed mail out HVAC Surveys completed**



# Building Characteristics



**Table 11. Building Characteristics Stratified by Business Type.**  
(Data are presented as percent of respondents answering “yes”)

Question/survey Strata	Non-Medical (%)	Health Care (%)	Restaurant (%)	Food store (%)	Retail store (%)	Lodging (%)	Public Assy. (%)	Services (%)	Misc. (%)	Other (%)
<b>Indoor Contaminant Sources</b>										
1st flr.: type of finish-carpet	94.0	83.7	46.0	18.2	61.7	100.0	100.0	78.7	89.6	90.5
1st flr.: type of finish-vinyl flooring	38.8	51.0	7.8	27.3	27.1		47.4	33.3	27.1	31.0
1st flr.: any fire damage		2.2	7.8		1.7		5.6	2.7	2.1	
1st flr.: any interior painting	34.5	55.3	49.0	40.0	28.8	40.0	55.6	46.7	34.8	61.9
1st flr.: any new carpet installed	18.3	19.1	11.8		6.8		16.7	18.7	21.3	33.3
1st flr.: new carpet type-natural fiber										
1st flr.: new carpet type-nylon	81.8	100.0			100.0			75.0	100.0	60.0
1st flr.: new carpet type-olefin	9.1		100.0				100.0	14.3		40.0
1st flr.: any new furniture installed	27.4	19.6	17.6		7.1	40.0	16.7	24.0	28.9	25.0
1st flr.: new furniture type-solid wood	48.1	44.4	44.4		25.0	100.0	33.3	50.0	33.3	40.0
1st flr.: new furniture type-comp. w/ veneer	33.3	44.4	55.6		75.0			61.1	50.0	55.6
1st flr.: new furniture type-encapsulated comp.	14.8	14.3						25.0	25.0	22.2
1st flr.: new furniture type-metal/plastic	55.6	88.9	33.3		50.0		66.7	61.1	50.0	66.7
1st flr.: new furniture type-other	14.8	33.3	11.1		50.0	50.0	33.3	11.1		
<b>Natural Ventilation</b>										
Space has windows that open	18.3	26.5	17.6		15.0	80.0	33.3	21.3	31.3	11.9
Windows are opened regularly	47.6	46.2	77.8		44.4	75.0	66.7	37.5	53.3	40.0
Doors are kept open	19.0	16.3	9.8	40.0	28.8	20.0	26.3	29.3	27.1	33.3
<b>Evidence of indoor contamination</b>										
Space has visible condensation	1.7	6.4	11.8	10.0			5.3	2.7	2.1	
Visible condensation on windows	100.0	66.7	100.0				100.0	100.0	100.0	
Visible condensation on walls		33.3								
Space has water damage or mold	6.9	2.1	9.8		6.8	20.0	5.3	5.3	10.4	7.1
<b>HVAC related questions</b>										
1st flr.: air cleaners used	10.3	14.0	14.3		8.8		5.6	9.9	8.7	14.3
1st flr.: space heaters used	30.1	22.7	4.0	20.0	12.1		11.1	35.1	26.1	31.0
1st flr.: humidifiers used	1.8	6.8	2.0		3.5					2.4



# Bld. Characteristics (2)

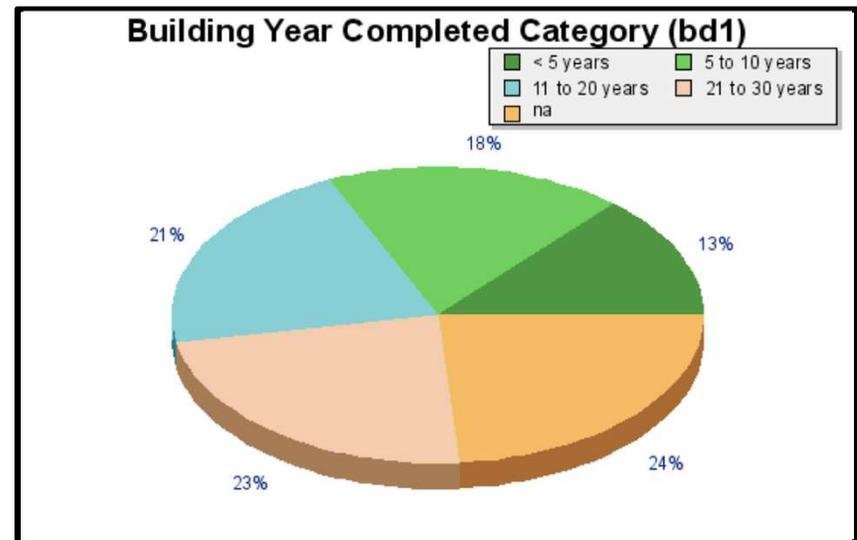
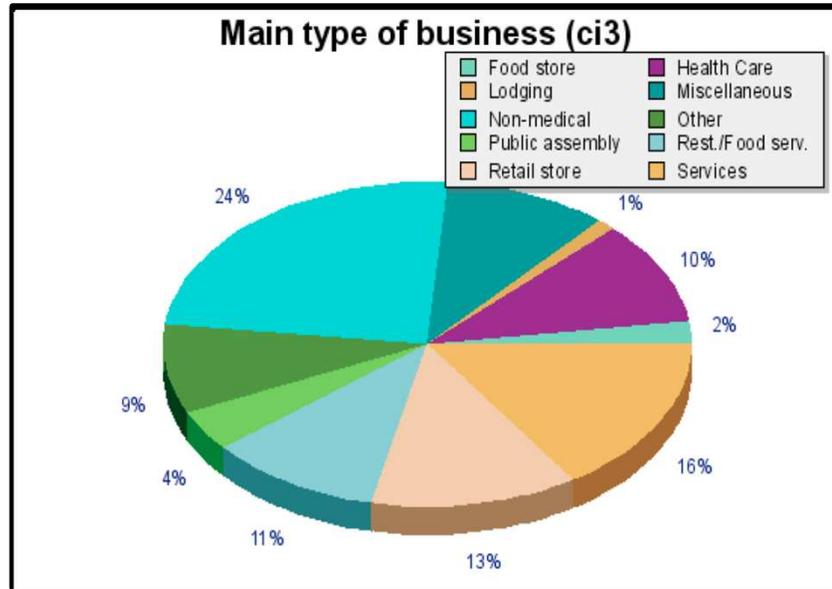


Table 11. Continued.

	Non-Medical (%)	Health Care (%)	Restaurant (%)	Food store (%)	Retail store (%)	Lodging (%)	Public Assy. (%)	Services (%)	Misc. (%)	Other (%)
Question/survey Strata										
1st flr.: dehumidifiers used	0.9	2.3	2.0	11.1	3.4			2.7	2.2	2.4
Number of AC settings when occup.	49.1	42.9	66.0	70.0	56.7	25.0	47.4	58.1	56.3	55.3
Number of AC settings when unoccup.	30.1	28.6	44.0	25.0	38.6	40.0	11.1	32.9	32.6	17.1
Number of heating settings when occup.	62.1	52.1	69.4	66.7	52.5	75.0	52.6	62.2	66.7	64.1
Number of heating settings when unoccup.	26.8	22.4	30.0	37.5	31.6	50.0	11.1	36.6	25.0	17.5
<b>Maintenance/cleaning</b>										
1st flr.: cleaned on regular schedule	98.2	100.0	100.0	100.0	100.0	100.0	100.0	97.3	95.7	100.0
Cleaning when occupants present	27.9	40.4	54.9	66.7	46.6	80.0	55.6	46.6	61.4	52.4
1st flr.: cleaned by outside contractor	76.8	53.2	30.0	55.6	58.6	40.0	38.9	67.1	54.5	61.9
1st flr.: cleaned with wet mop	80.6	97.9	96.1	100.0	78.9	100.0	88.2	89.7	90.9	79.5
1st flr.: cleaned with dry mop	27.3	45.2	44.0	77.8	48.1	40.0	50.0	49.2	48.8	50.0
1st flr.: cleaned with vacuum	98.2	93.6	56.0	55.6	82.8	100.0	100.0	84.5	90.7	95.2
1st flr.: window cleaner used	84.2	89.1	96.0	100.0	86.2	100.0	77.8	92.9	92.7	85.0
1st flr.: flr./furniture wax used	39.0	53.3	24.0	66.7	47.3	40.0	38.9	41.8	39.0	25.0
1st flr.: bleach used	25.6	52.4	52.0	44.4	19.2	80.0	33.3	34.5	36.6	40.5
1st flr.: carpet cleaner used	63.8	66.7	38.0	33.3	48.2	100.0	88.9	58.2	42.9	57.5
1st flr.: pesticide regularly applied	61.9	72.7	77.1	55.6	42.9	80.0	61.1	58.3	55.6	57.1
<b>Occupant feedback</b>										
Occupant complaints: too hot	55.2	61.7	44.9	11.1	39.7	60.0	55.6	50.7	45.7	61.9
Occupant complaints: too cold	57.8	63.8	44.9	44.4	39.7	60.0	72.2	56.2	43.5	59.5
Occupant complaints: too drafty	4.3	13.0	4.1	11.1			5.6	11.0	2.2	11.9
Occupant complaints: no air movement	10.3	17.0	6.1		5.2		16.7	16.4	17.4	11.9
Occupant complaints: odors	7.8	19.1	8.2		10.3	20.0	11.1	23.3	21.7	11.9
Occupant complaints: something else	2.6				1.7		5.6	1.4	2.2	2.4
<b>Locale</b>										
Surrounding area: rural, etc.	34.5	44.9	40.8	10.0	40.7	25.0	26.3	34.7	43.8	36.6
Surrounding area: industrial, etc.	30.2	10.2	2.0	10.0	10.0	.	5.3	24.0	29.2	23.8

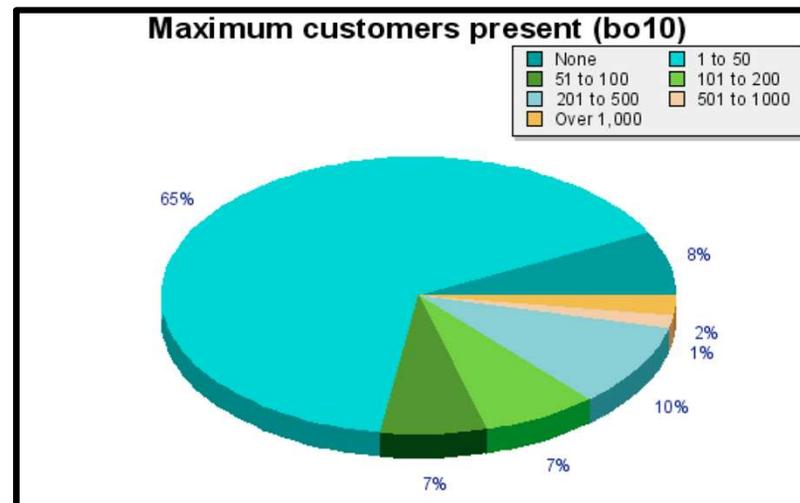
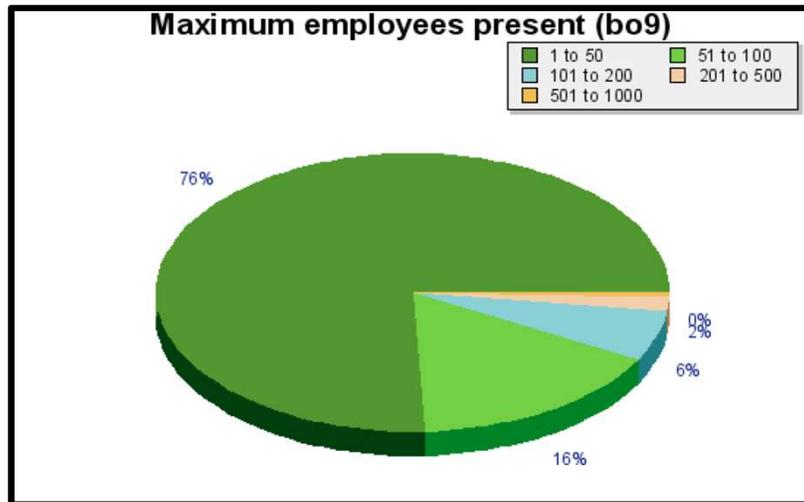


# Sample by Main Business Type



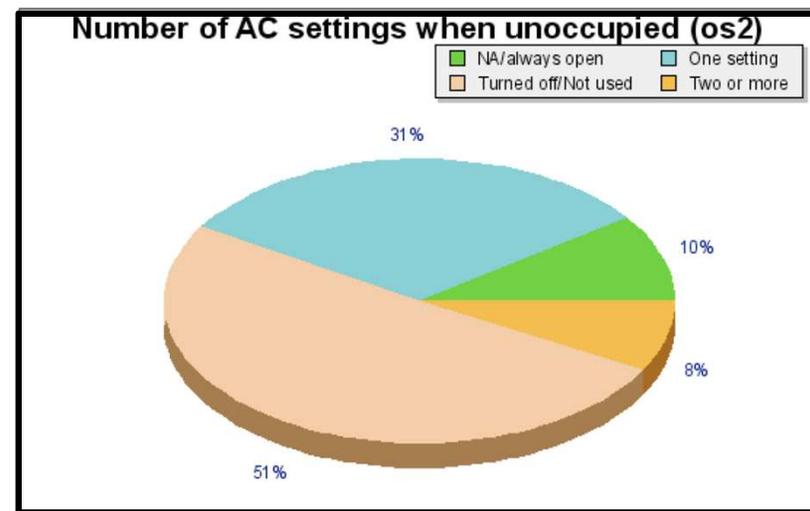
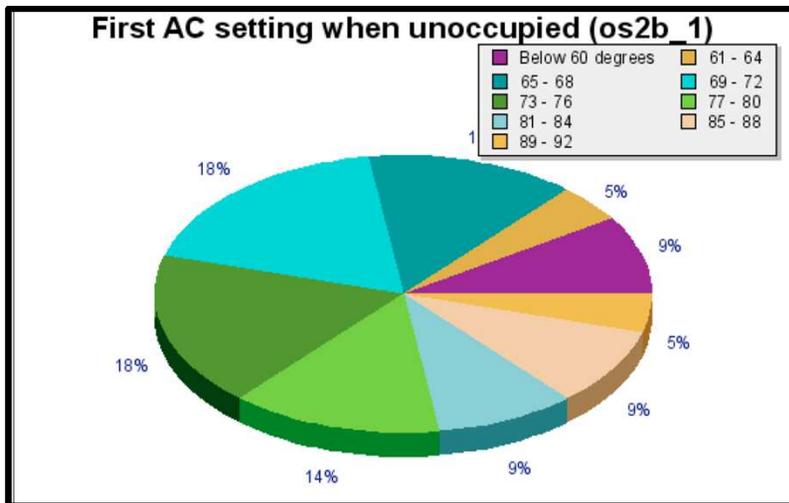
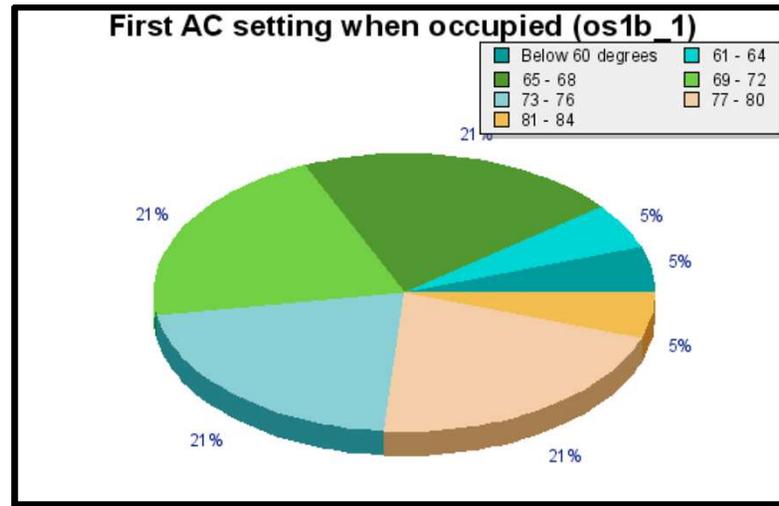


# Occupancy



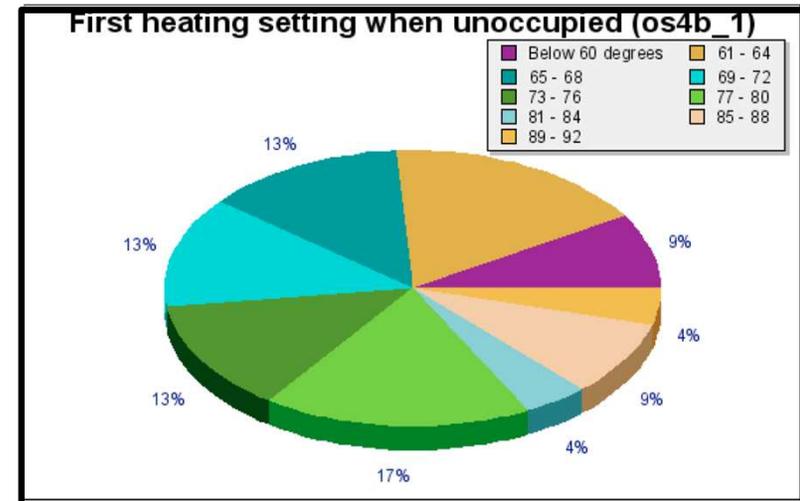
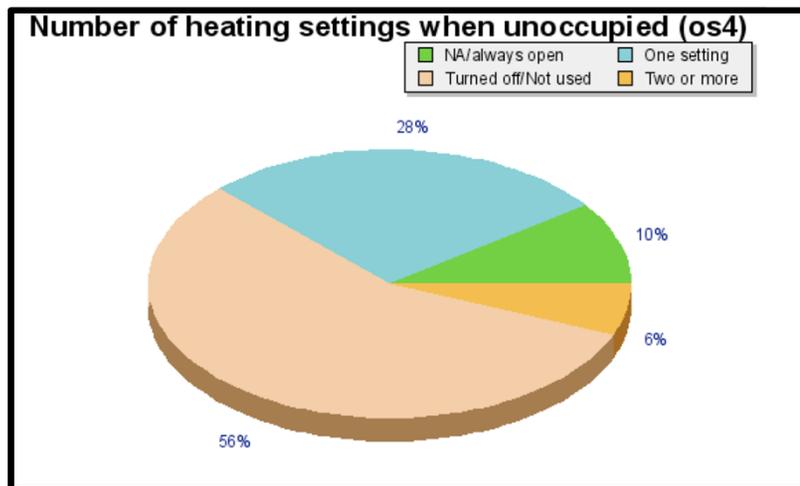
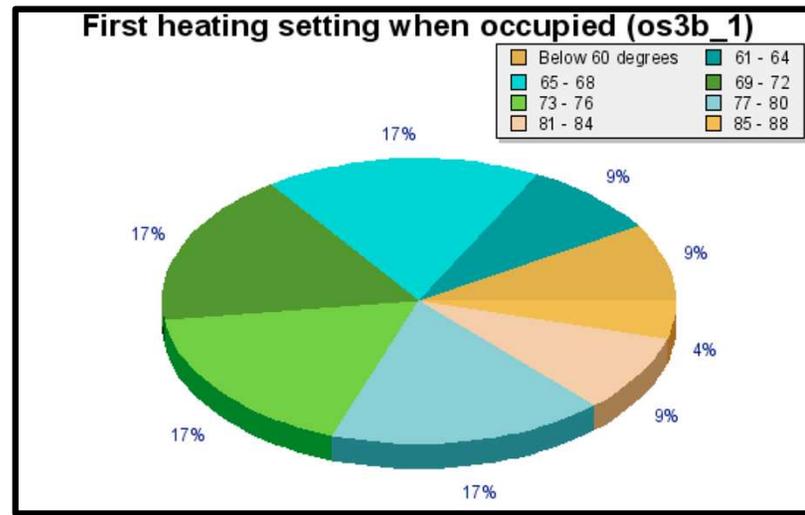


# Thermal Conditioning: AC



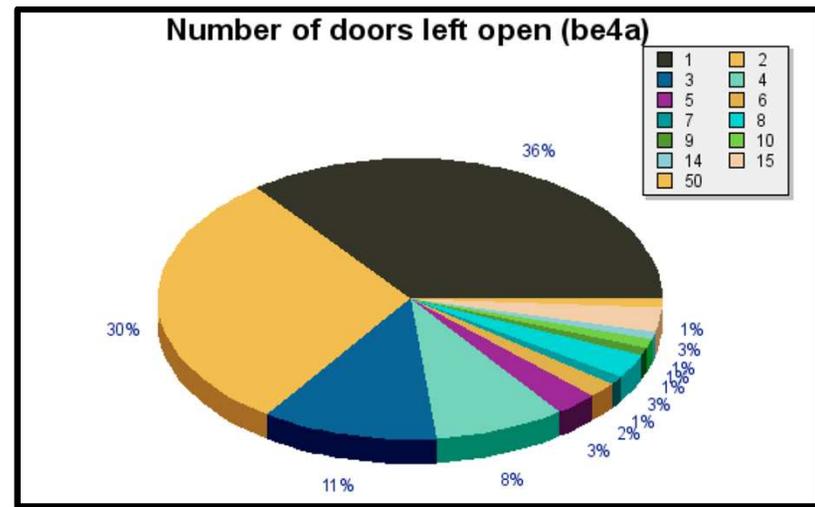
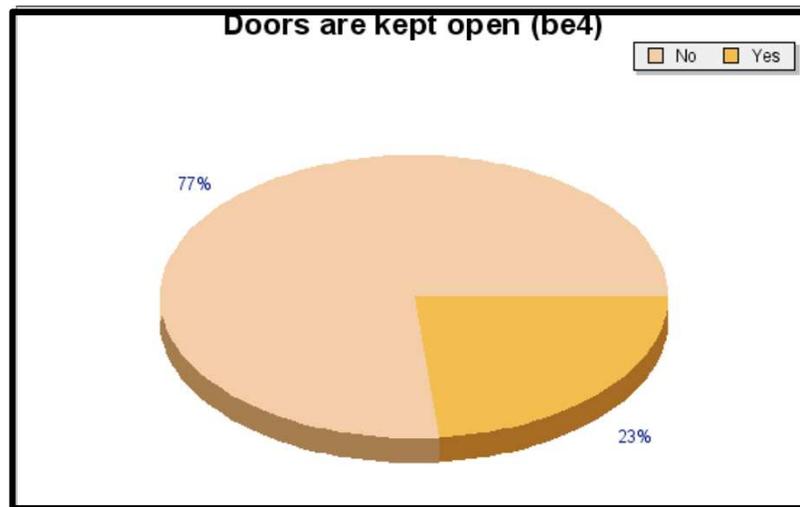
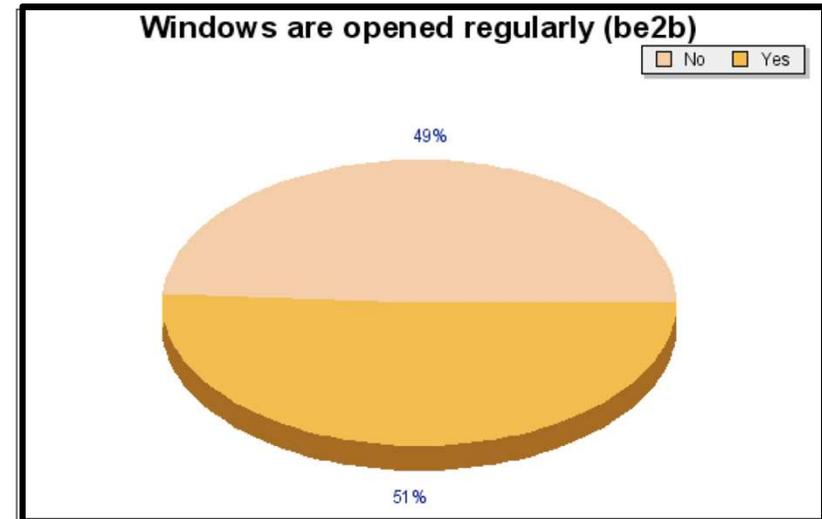
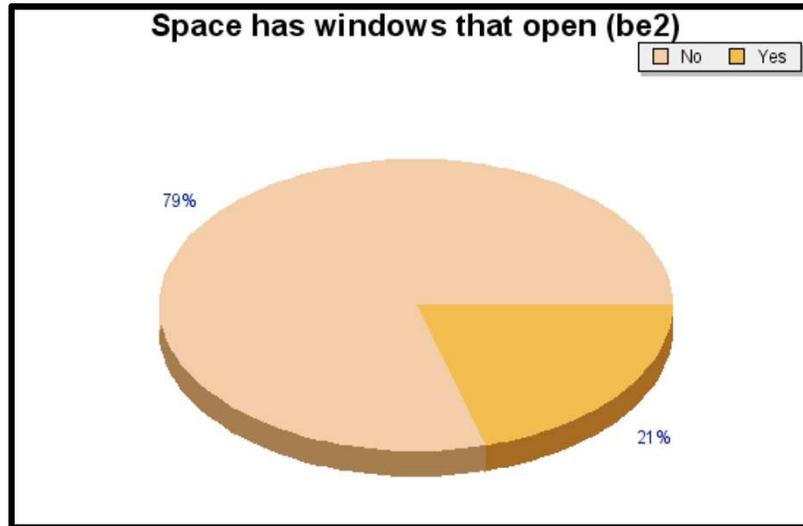


# Thermal Conditioning: Heating



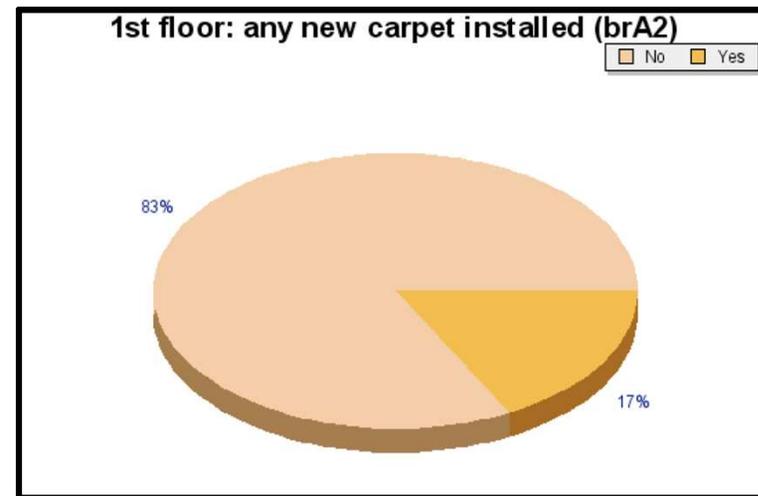
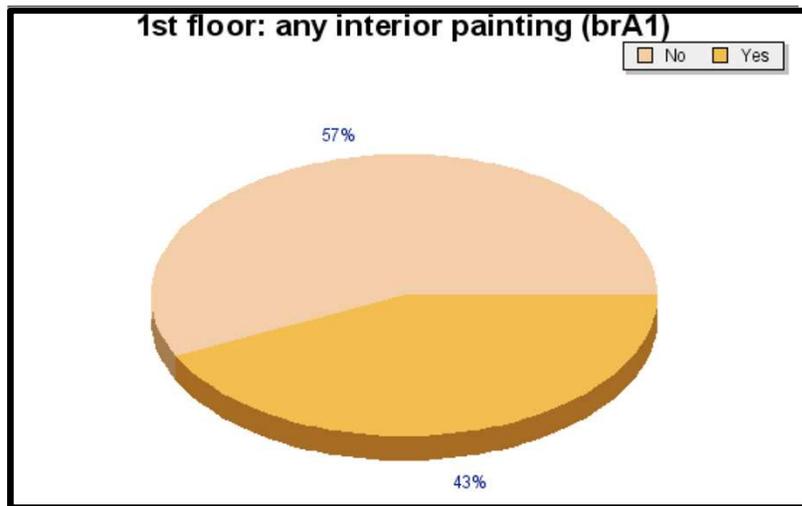
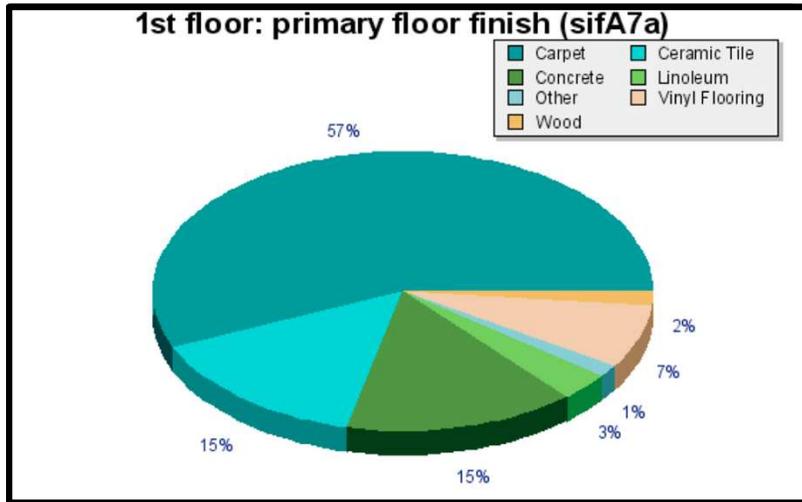


# Natural Ventilation



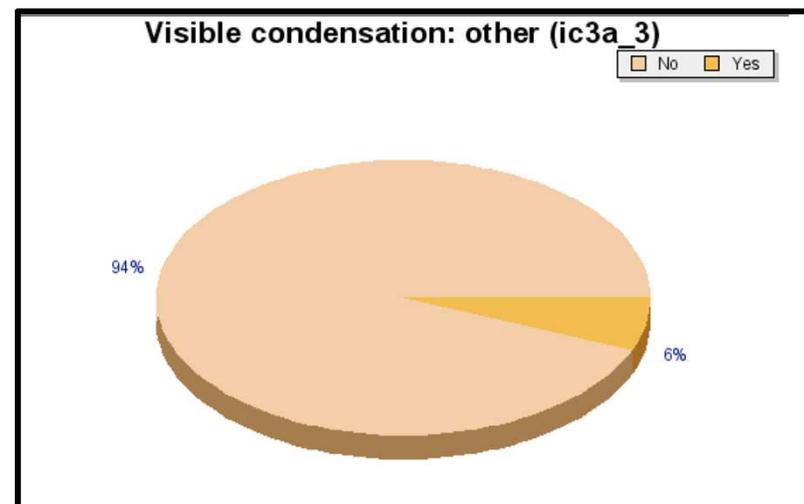
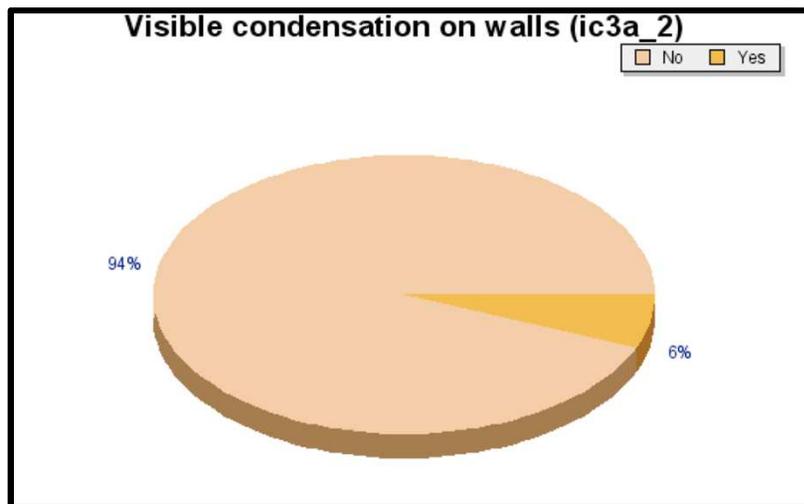
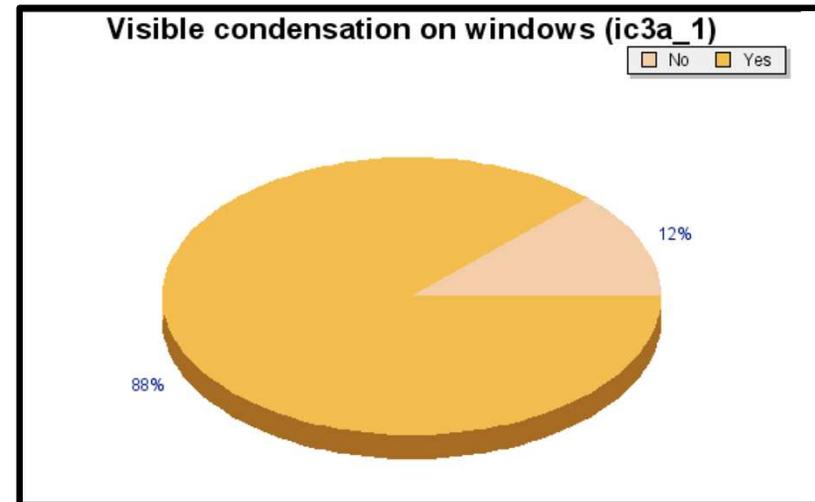
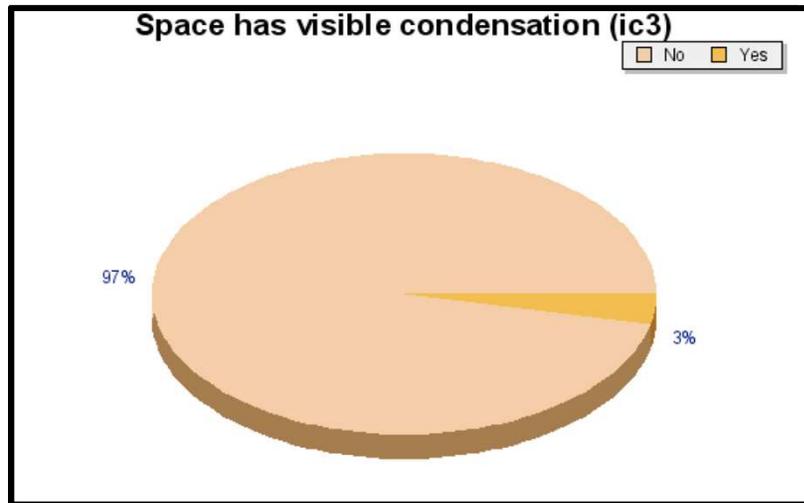


# Floor Finish



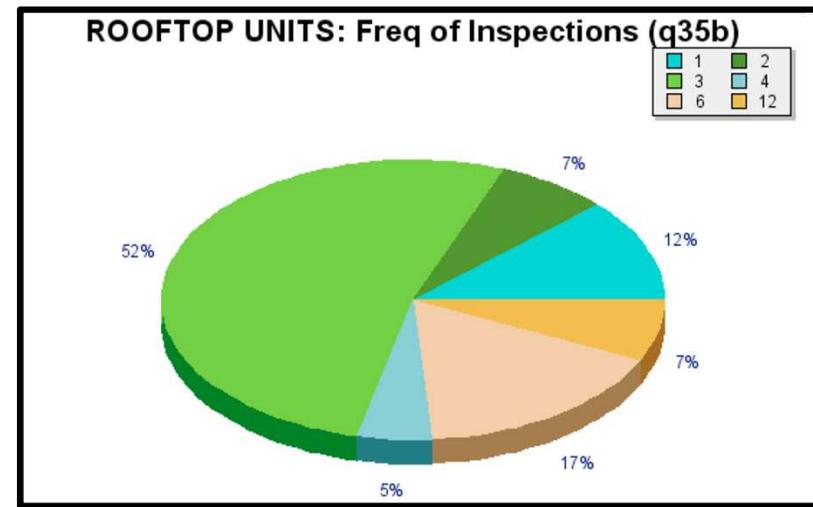
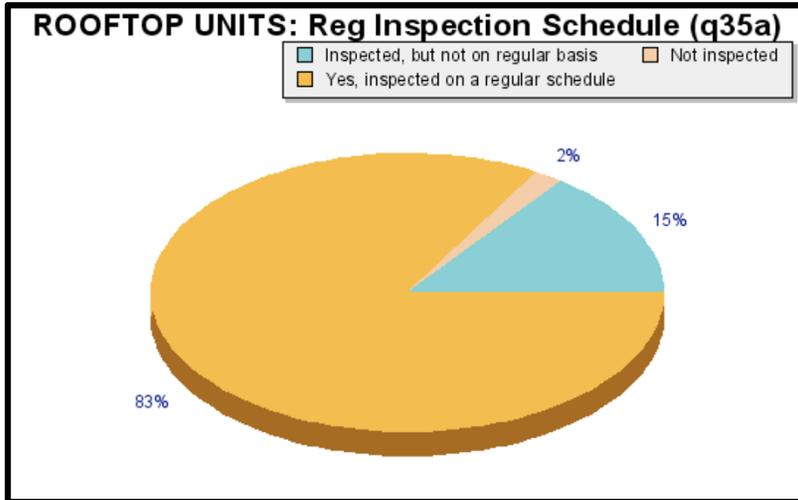


# Indoor Contaminants: Condensation





# Maintenance: HVAC



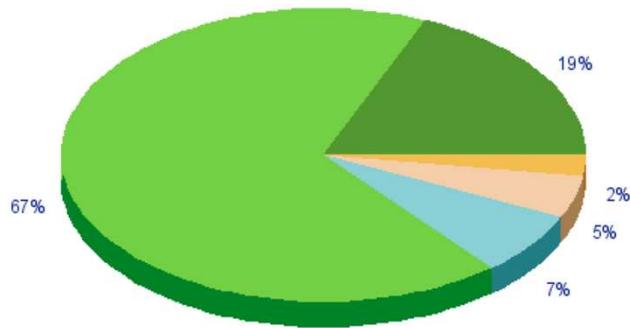


# Minimum Outside Air Control



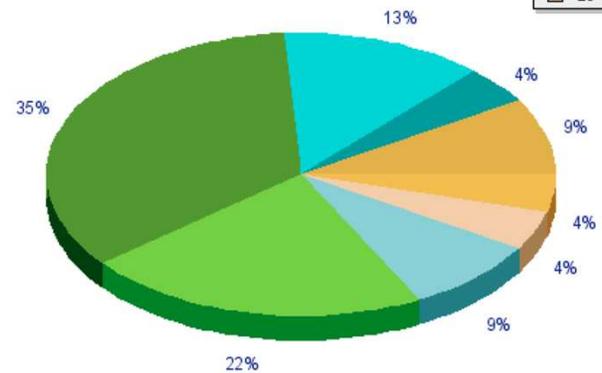
Maintaining Minimum Outdoor Air Flow (q25)

- Demand Controlled Ventilation
- Fixed damper position
- Intake airflow monitoring
- Supply/return fan tracking
- Something else



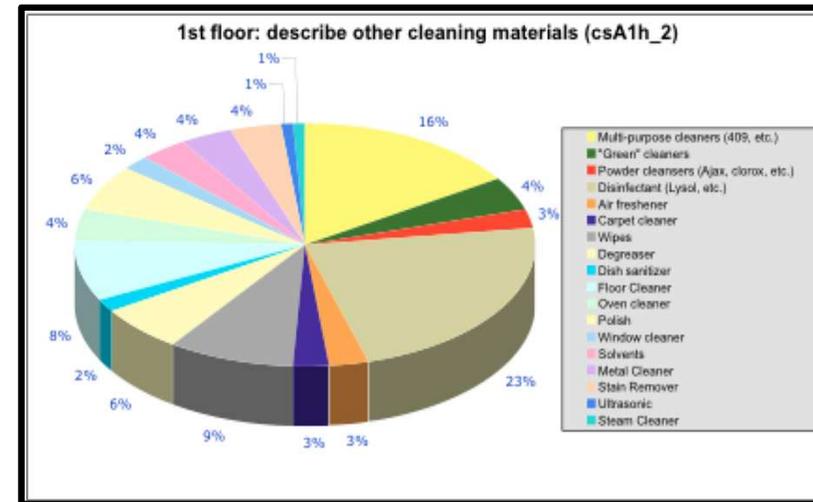
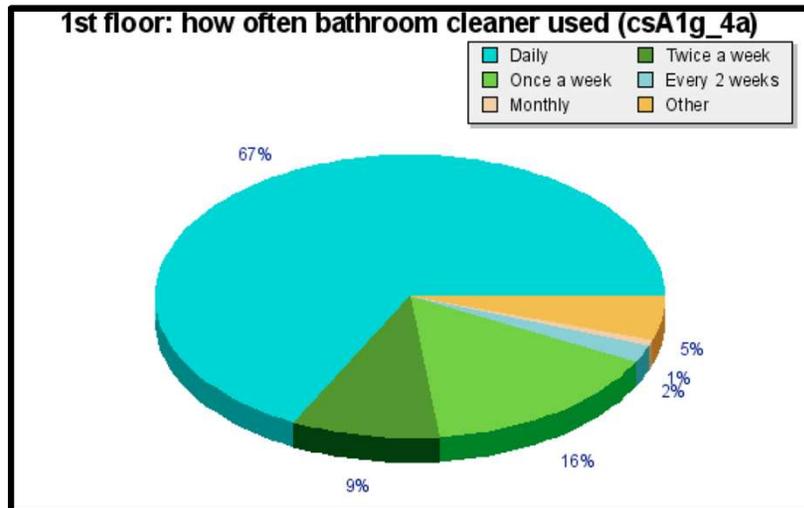
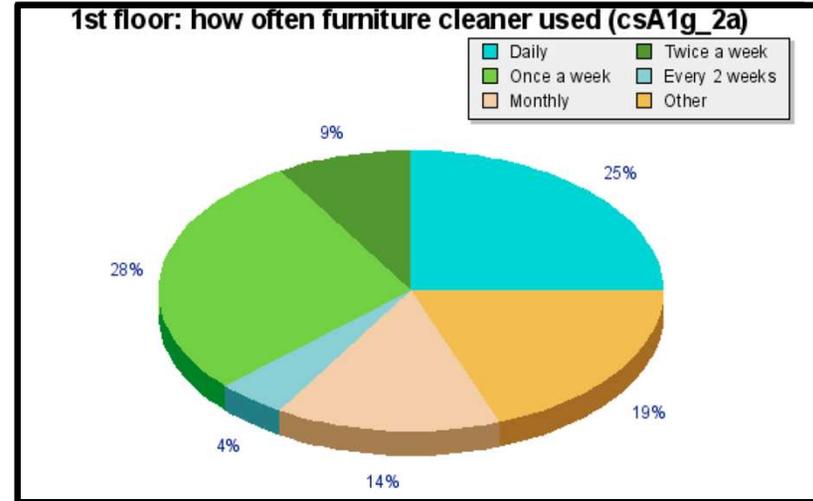
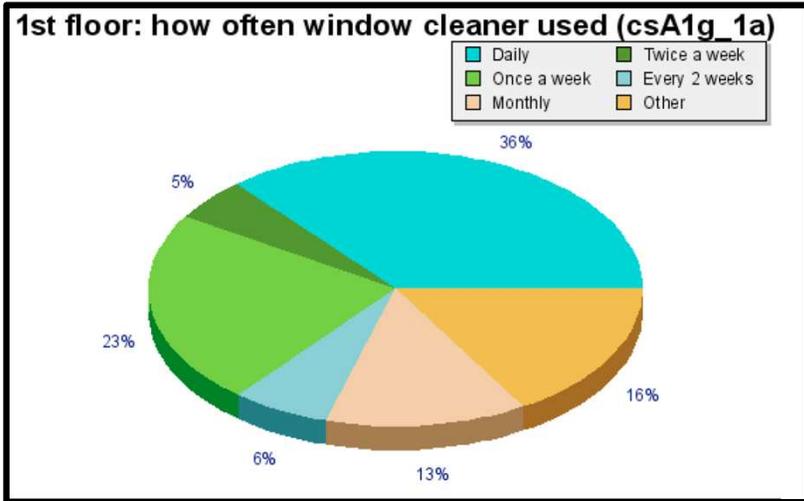
Minimum Outdoor Air Setting (Pct) (q26)

- 5
- 8
- 10
- 15
- 20
- 25
- 28
- 50



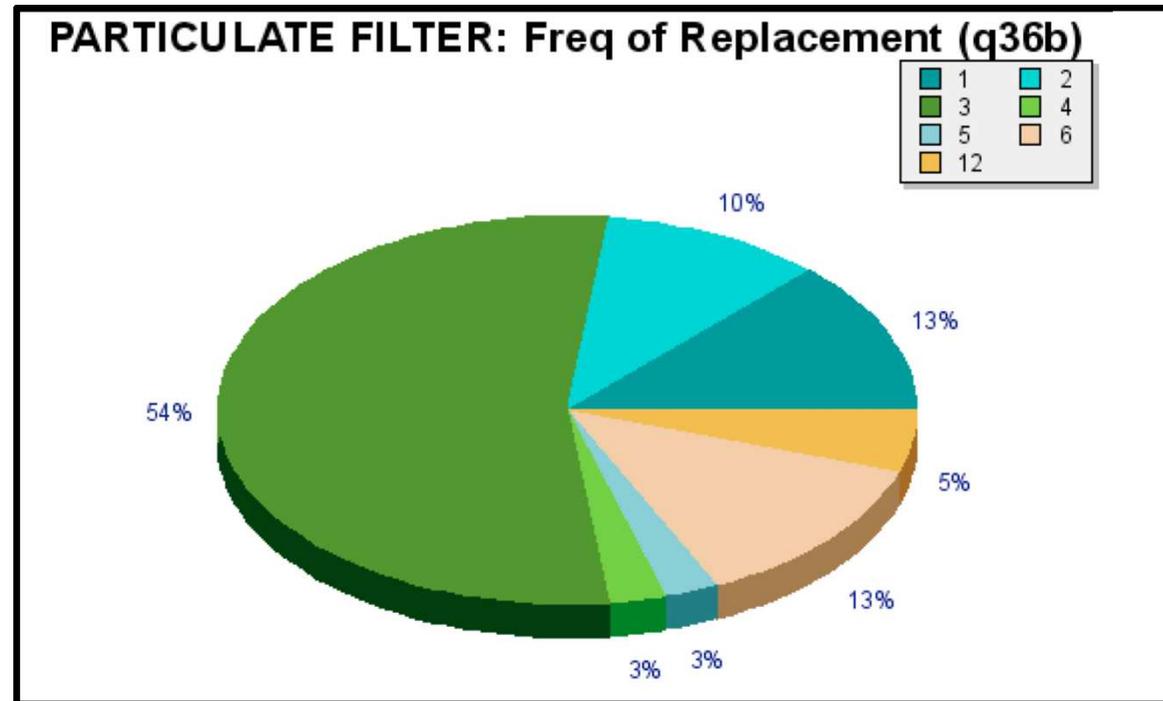


# Indoor Cleaning Sources



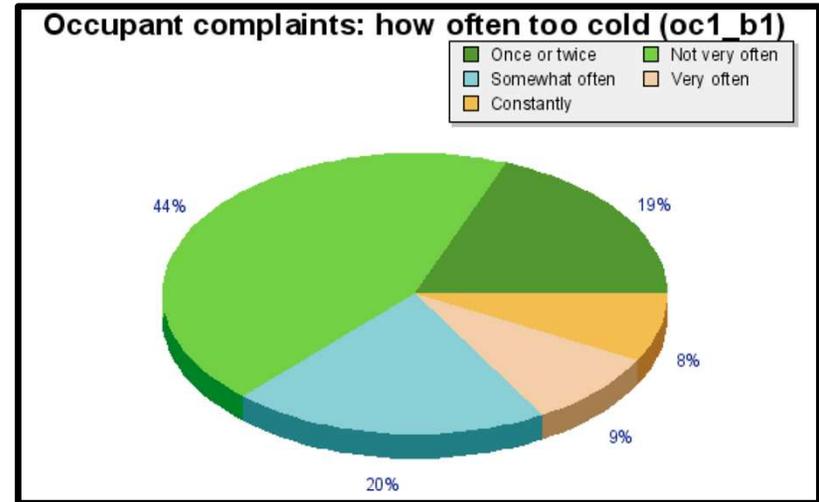
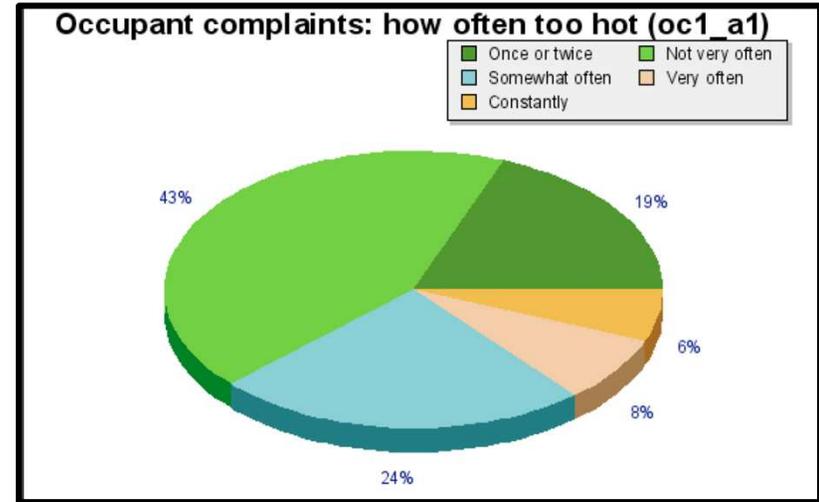
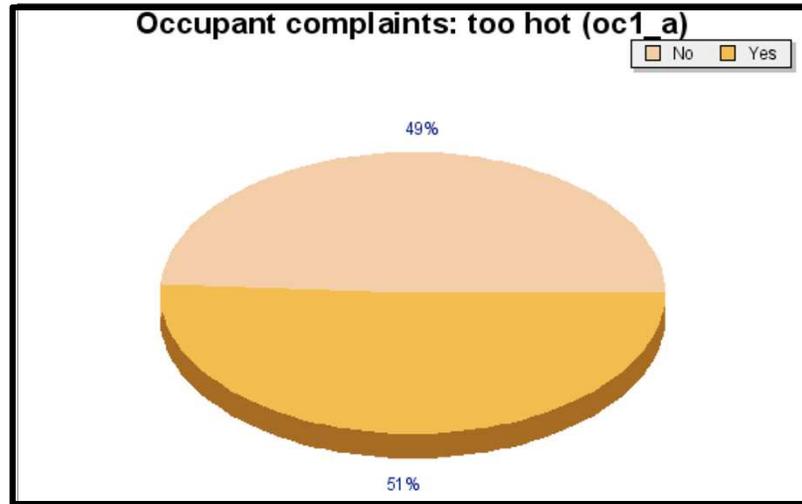


# Filter Maintenance



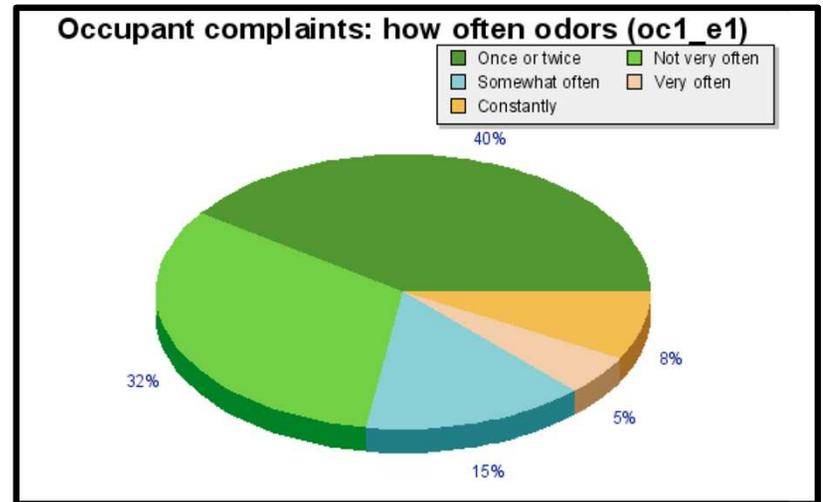
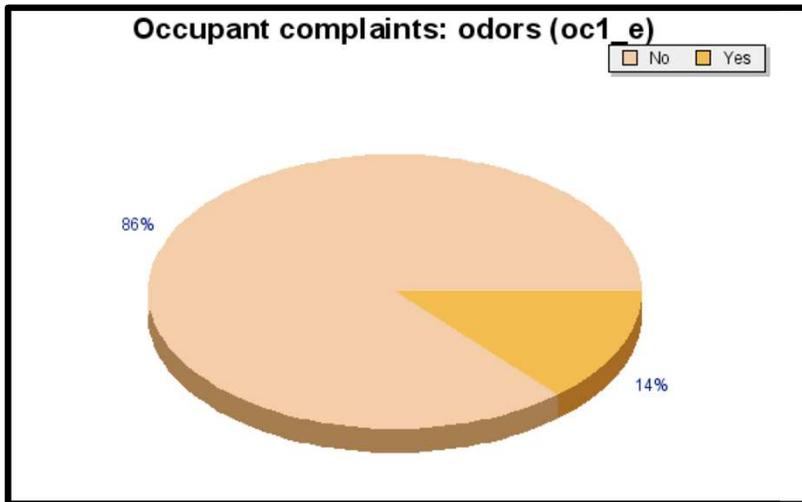
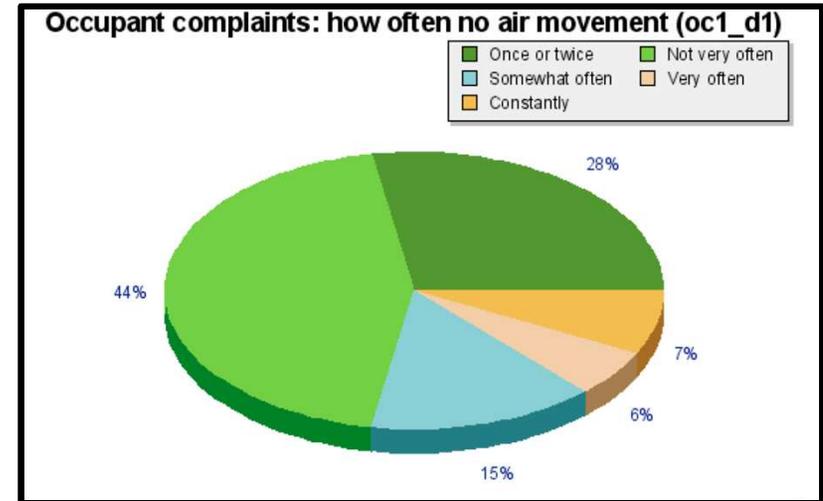
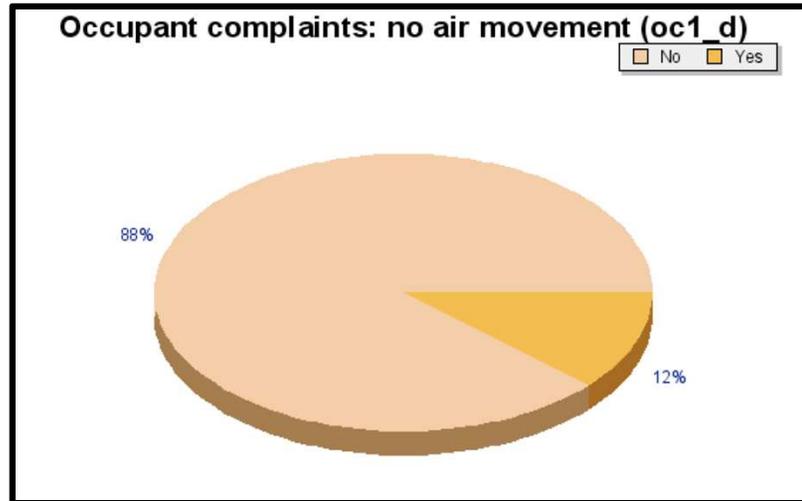


# Thermal Conditions





# Complaints



Corrective actions: manager (32%) or supervisor (47%), contractor (20%), unspecified(16%)



# Objectives



- **Objective 1. Characterize HVAC/Ventilation Equipment**

- Small sample size (71 completed surveys)
- Some information OA ventilation control methods (67% on fixed damper)
- Most buildings had low efficiency filters ( 1 MERV 12, 3 HEPA)
- Overall, very standard systems

- **Objective 2. HVAC/ventilation operation and maintenance**

- Most buildings had reasonable temperature setpoints
- 38% over cooled
- 12% over heated
- Significant heating and cooling in unoccupied hours
- 30-60 minute pre-occupancy conditioning popular
- Fans typically on thermostatic control: intermittent ventilation
- Little knowledge of outdoor supply rates

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- Regular maintenance common in ~ 80% of SMCBs surveyed



# Objectives



- **Objective 3. SMCB functions, indoor sources, where applicable the intensity of source usage, and water and fire damage history**
  - Potential Sources: Floor and Wall Coverings; Furniture; Processes; Cooking; Cleaning
  - Carpet most common flooring material
  - New furniture common in 10% of buildings
  - Many cleaning activities
  - Significant pesticide application activities (mostly professional)
  - Water condensation, mold, water damage reported in 3.4% of building
  - Fire damage in 2% of buildings
- **Objective 4. History of IAQ complaints in building and associated remedial actions.**
  - History IAQ complaints merely reported by building manager (not very accurate)
  - Complaints of too hot and too cold about equal, likewise “drafty” and “no air movement”
  - Corrective actions likely to have come internally rather than by contractor



# Future Work



- **This work has been followed by SMCB Phase 2**
- **Larger sample of Buildings:**
  - Better broad characterization of HVAC systems, operation, and maintenance
  - Further characterization of product emissions
  - Detailed information of occupant health and productivity