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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 <50,000 ft²**
- **~10% of US Commercial Buildings in California**
- **Almost no information 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



- **Constructed after 1978**
- **Floor area between 1,000 and 50,000 ft²**
- **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



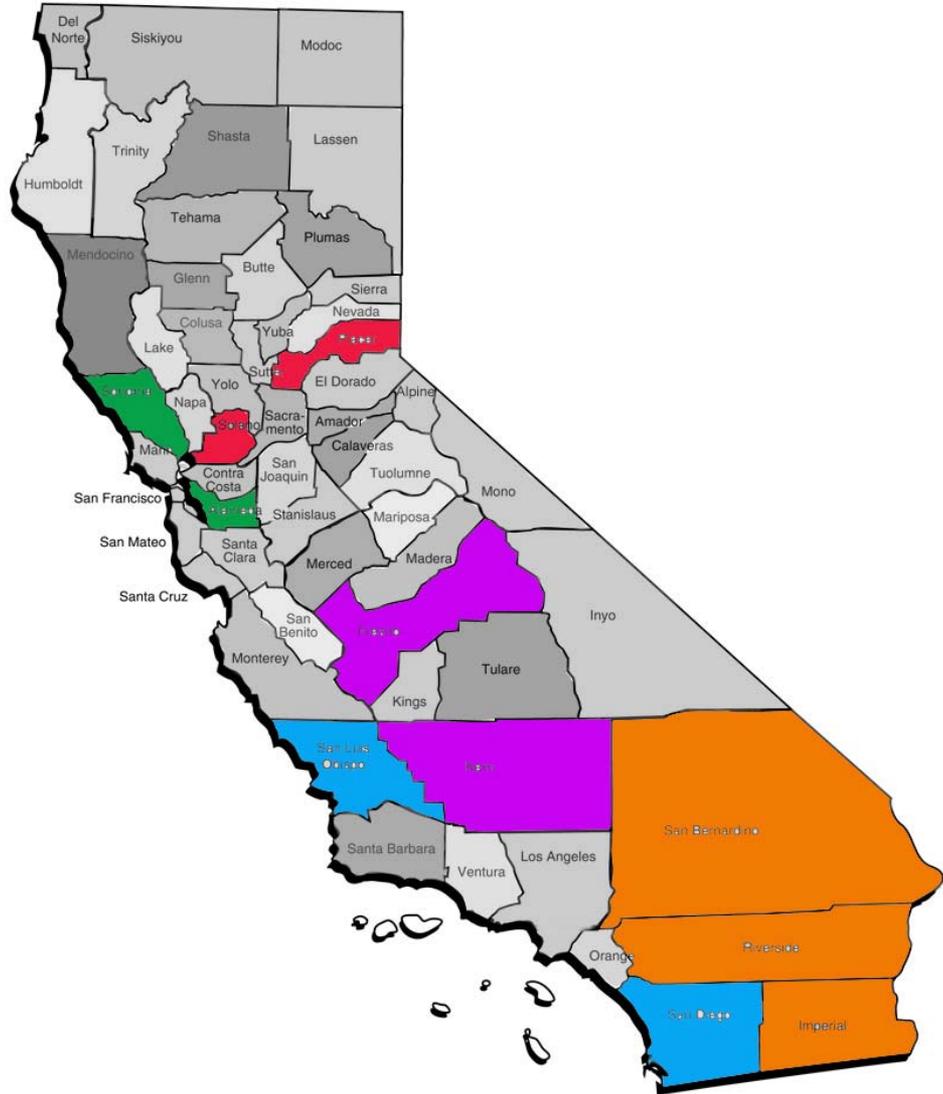
- **Survey using D&B database**
 - Telephone Survey
 - D&B has no building age data
 - Necessary to increase probability of reaching newer buildings
 - Selected fastest growing CA counties
 - Difficulty obtaining HVAC characteristics on phone
 - Mailback supplementary HVAC equipment survey



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



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 (%)
Indoor Contaminant Sources										
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		
Natural Ventilation										
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
Evidence of indoor contamination										
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
HVAC related questions										
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)

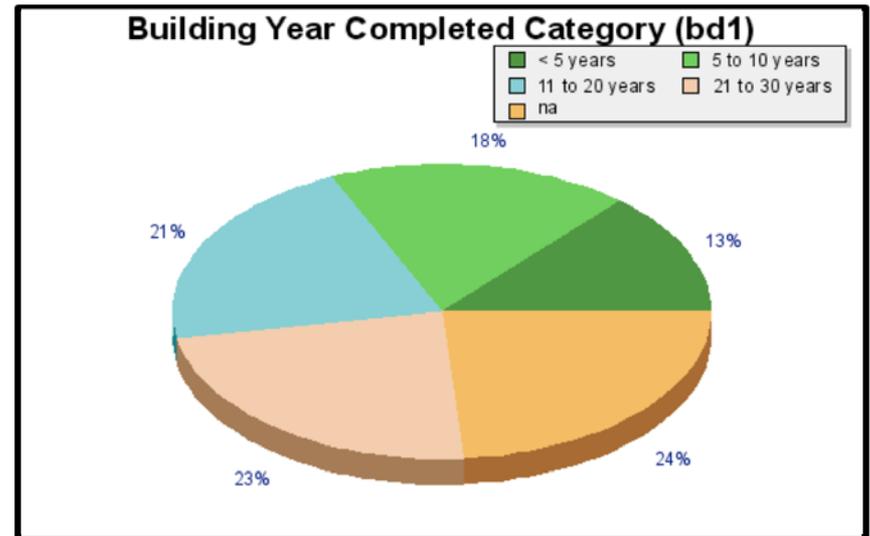
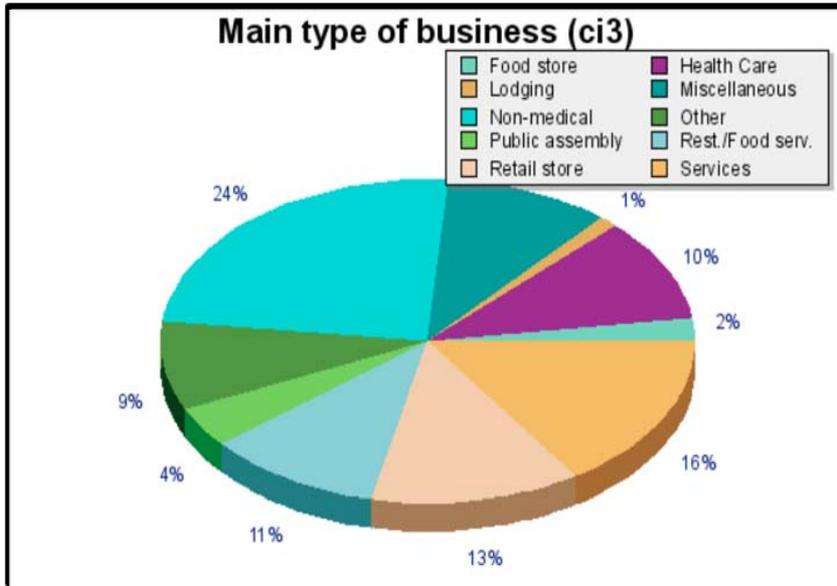


Table 11. Continued.

Question/survey Strata	Non-Medical (%)	Health Care (%)	Restaurant (%)	Food store (%)	Retail store (%)	Lodging (%)	Public Assy. (%)	Services (%)	Misc. (%)	Other (%)
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
Maintenance/cleaning										
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
Occupant feedback										
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
Locale										
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

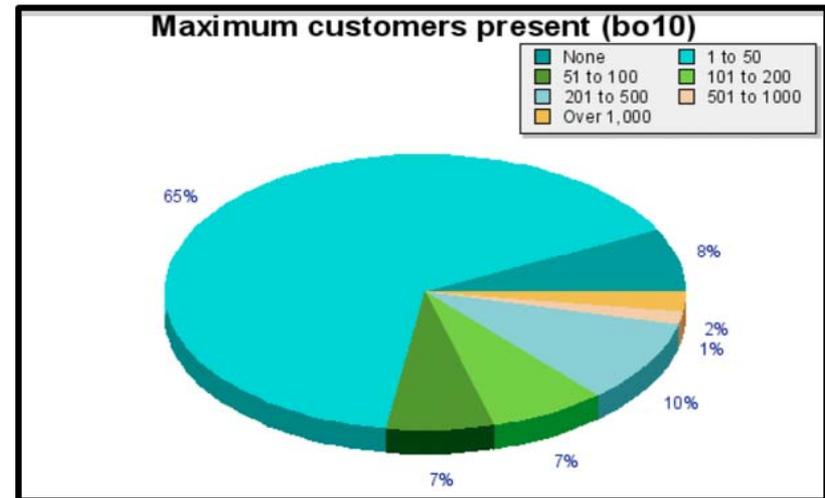
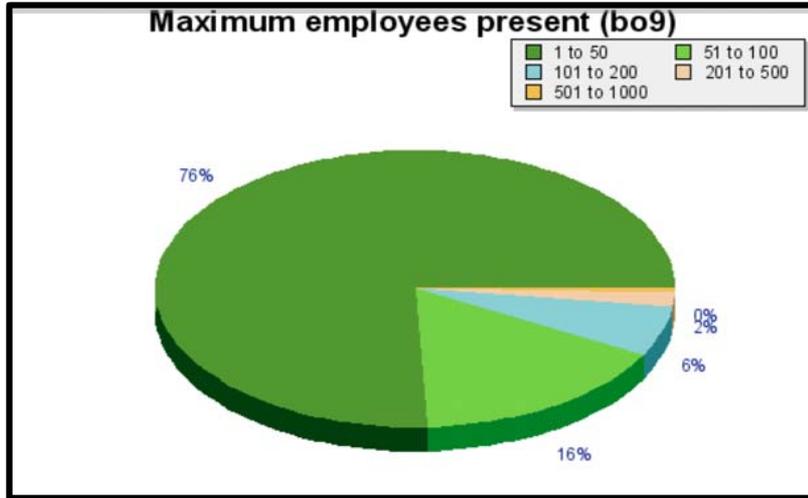


Sample by Main Business Type



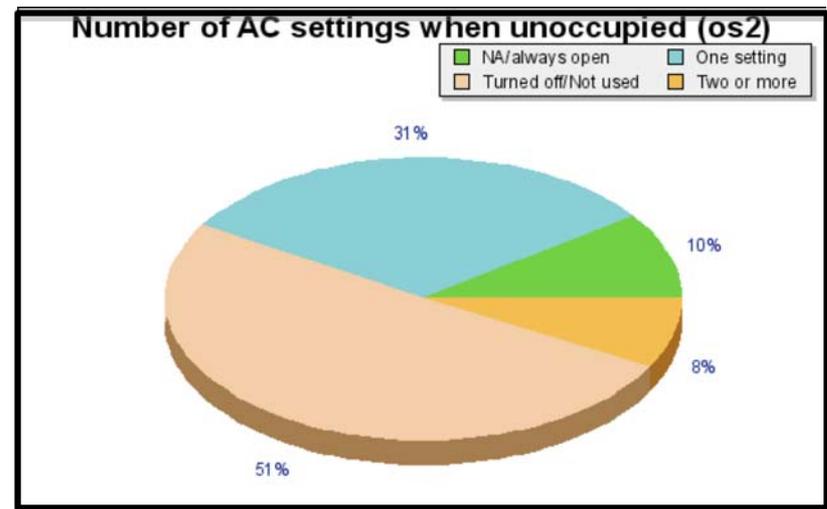
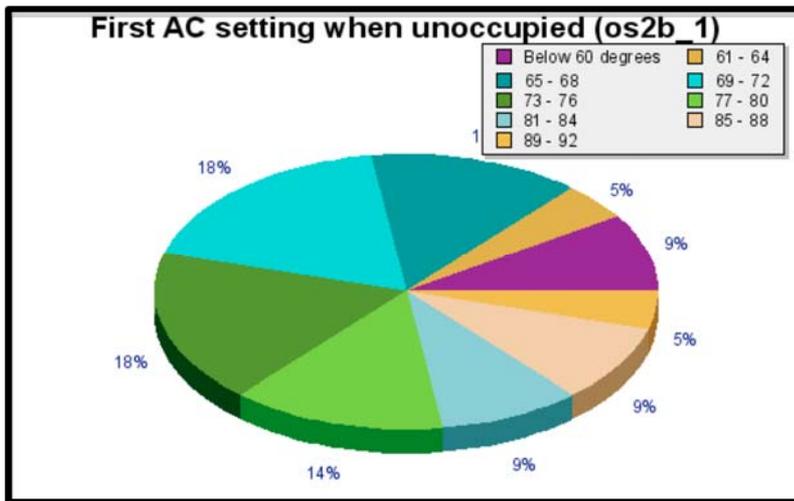
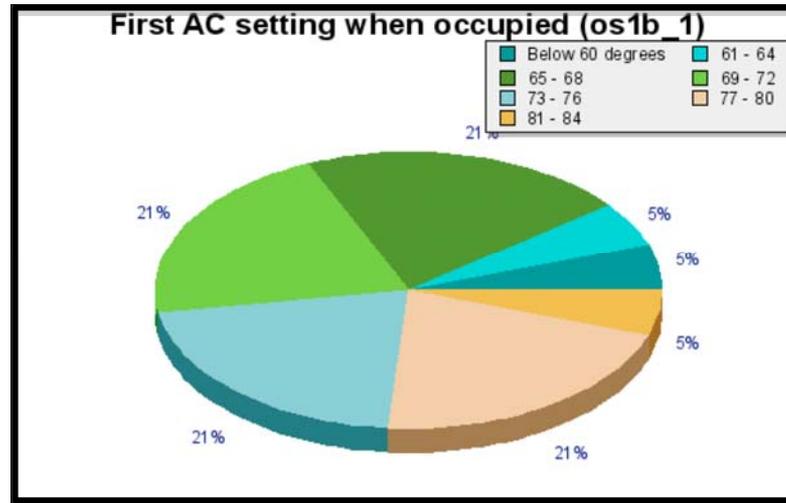


Occupancy



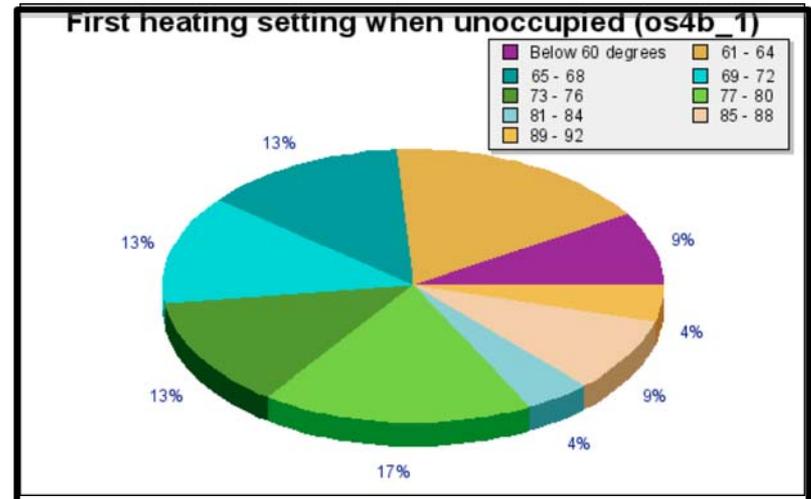
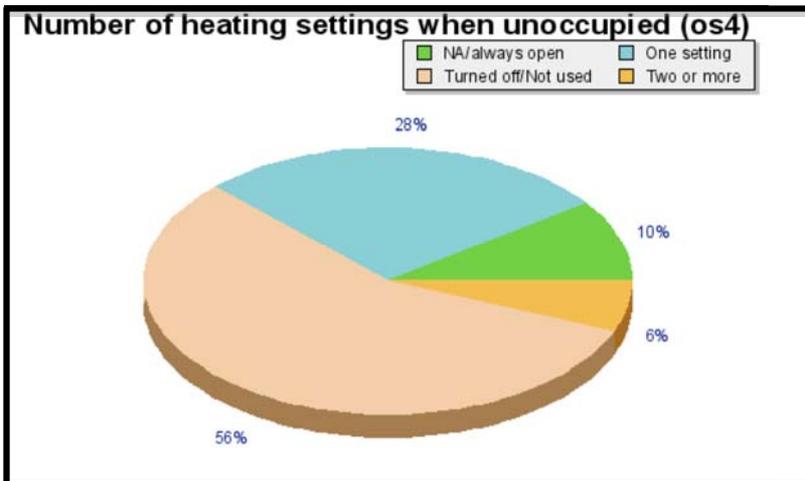
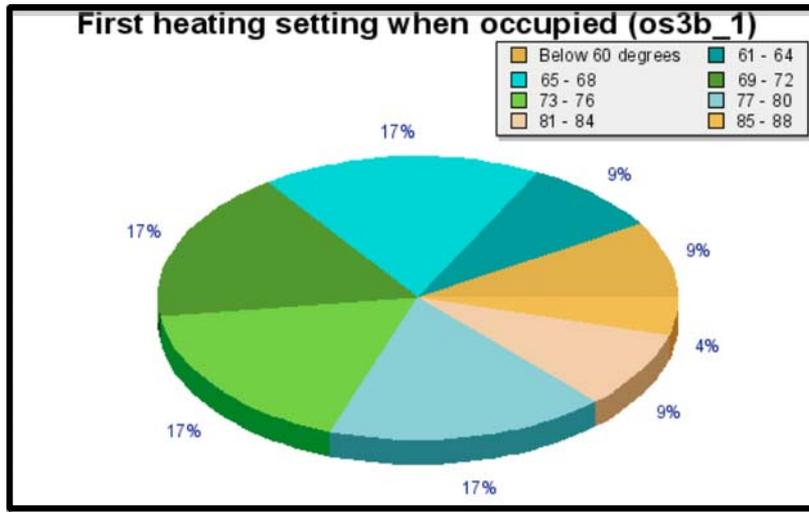


Thermal Conditioning: AC



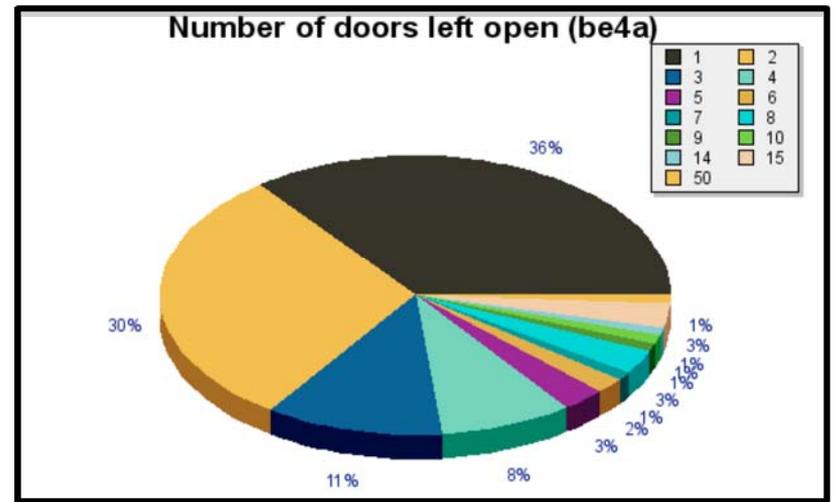
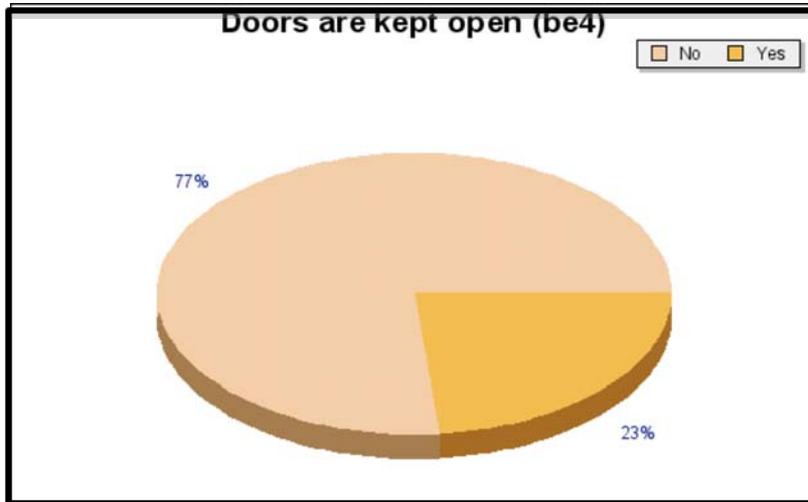
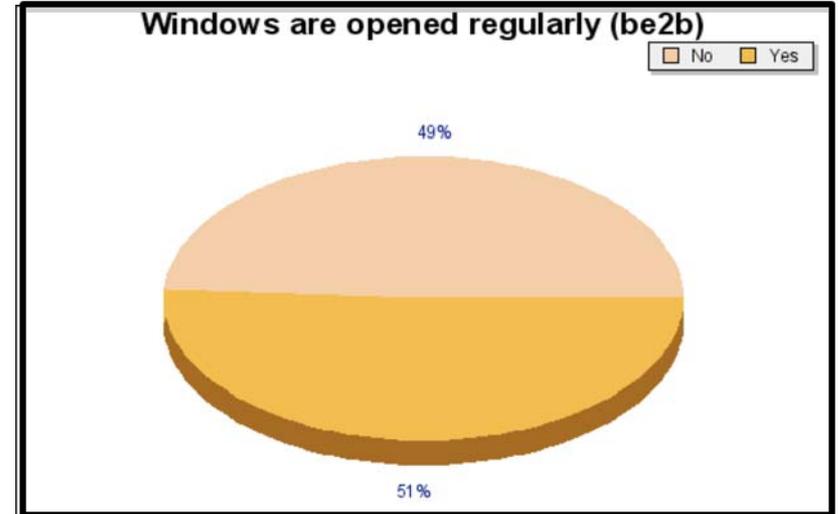
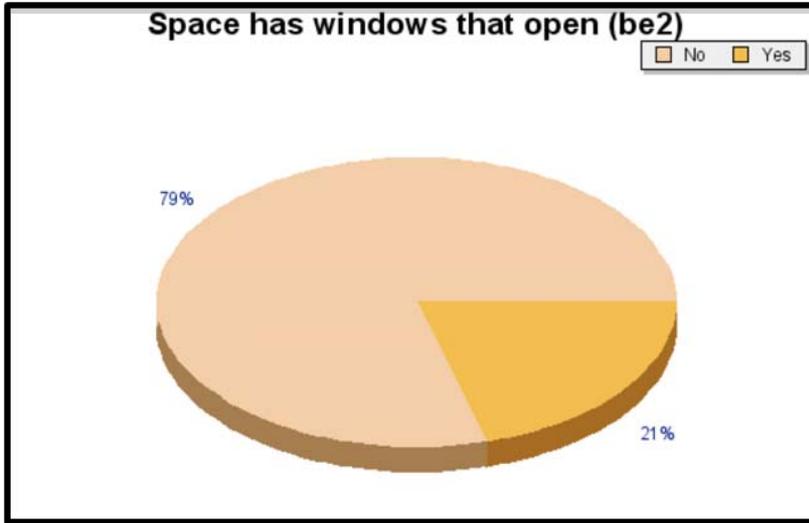


Thermal Conditioning: Heating



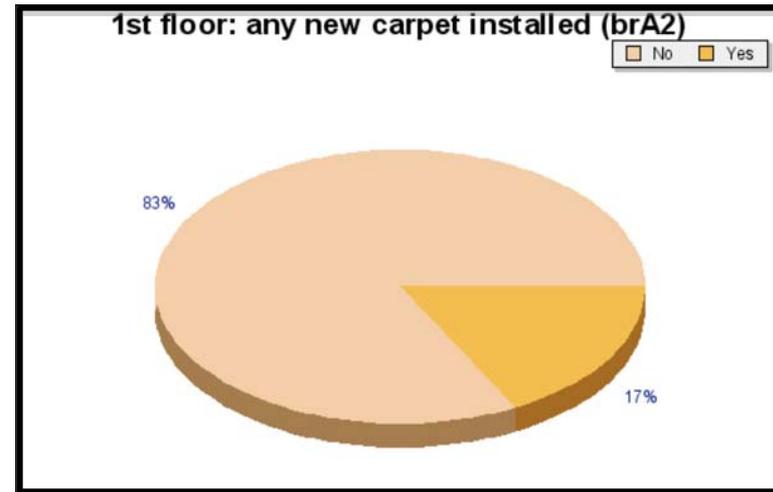
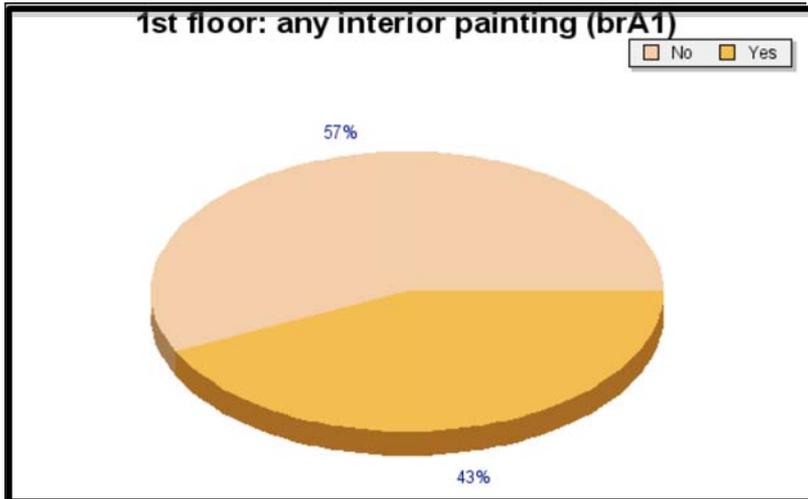
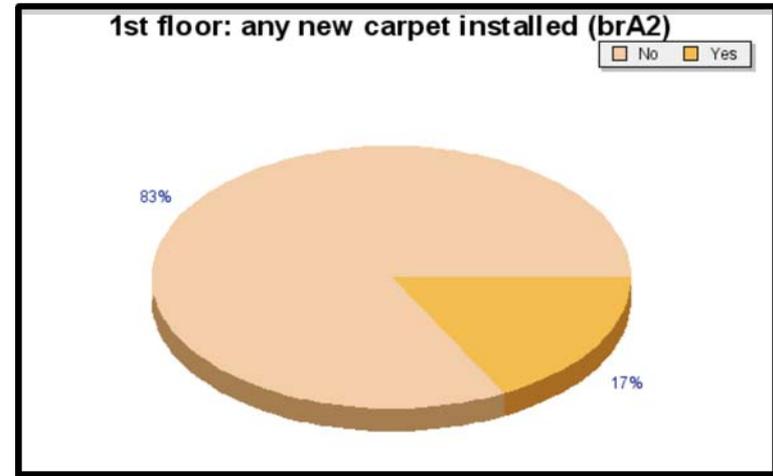
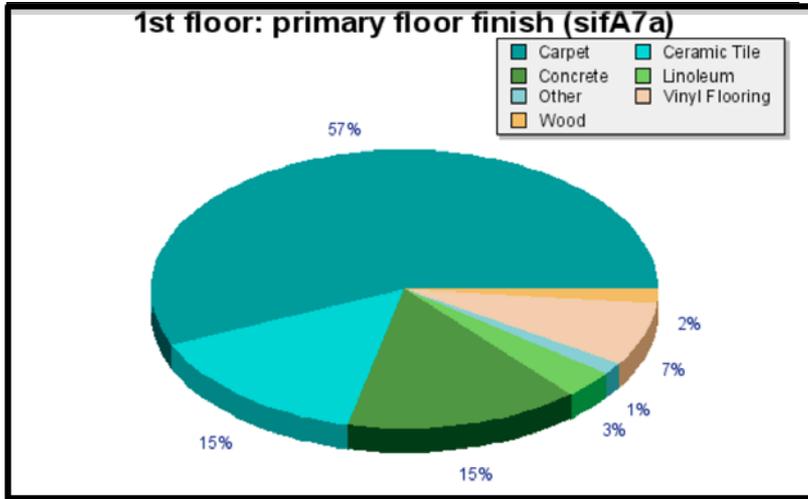


Natural Ventilation



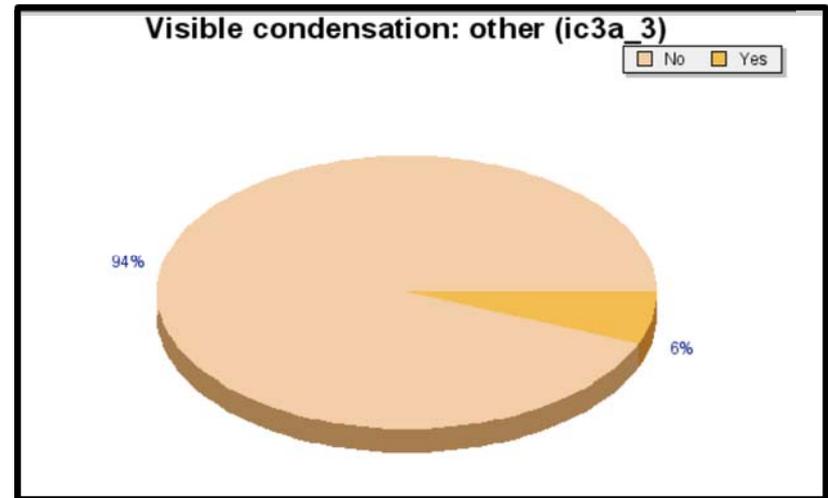
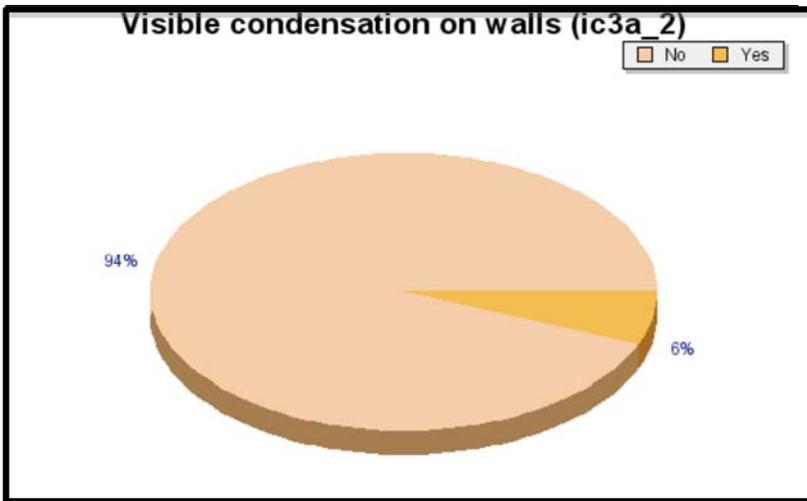
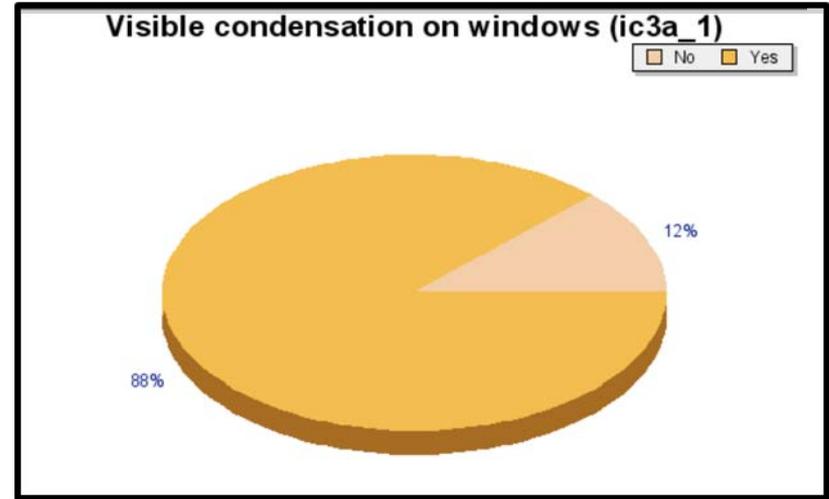
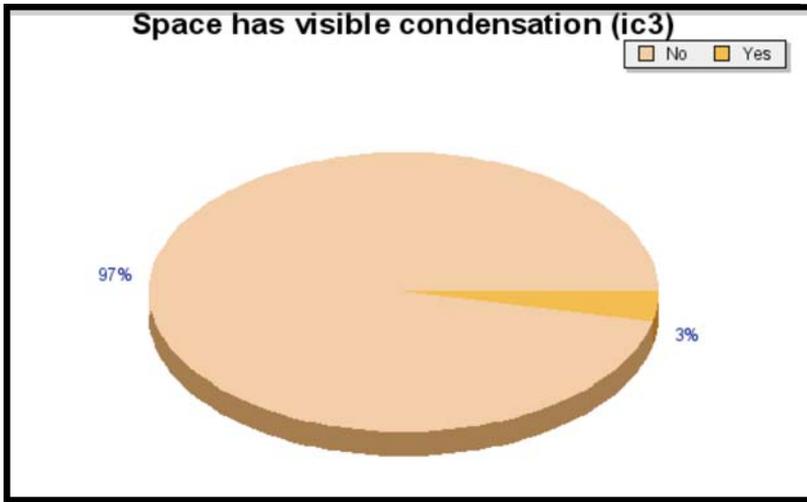


Floor Finish



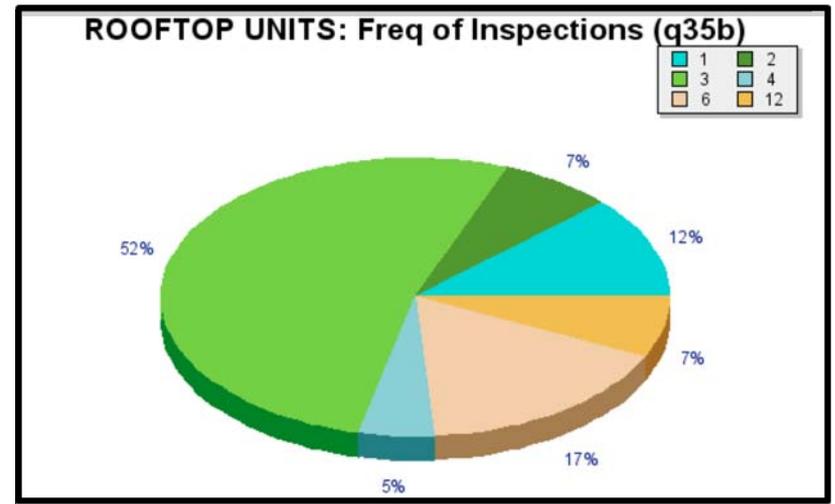
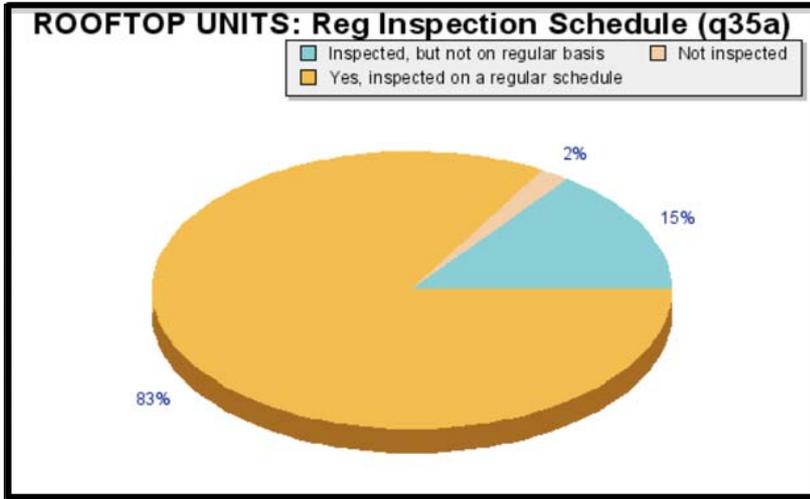


Indoor Contaminants: Condensation



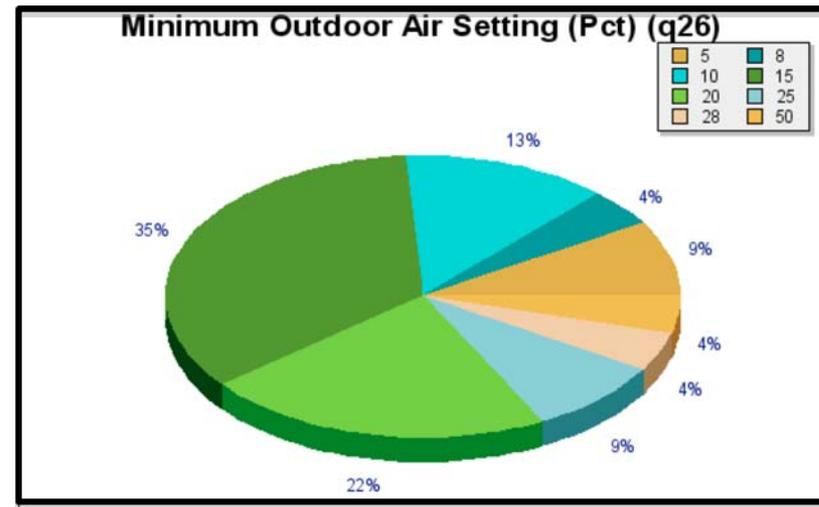
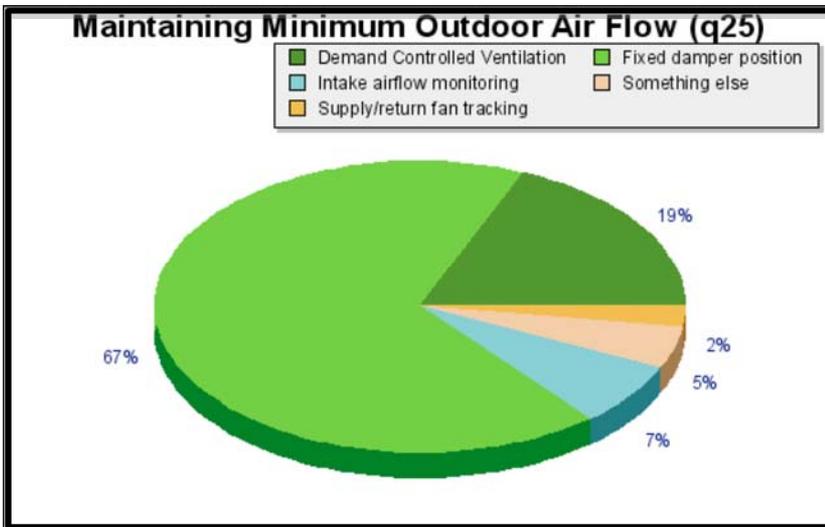


Maintenance: HVAC



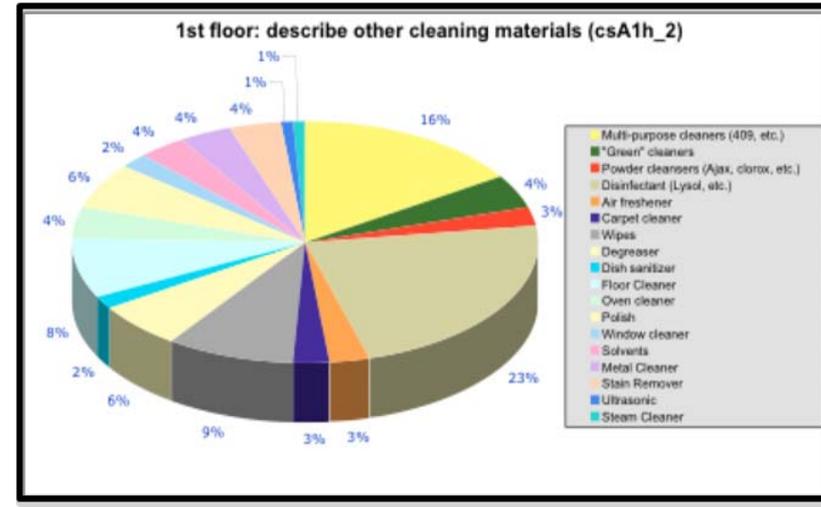
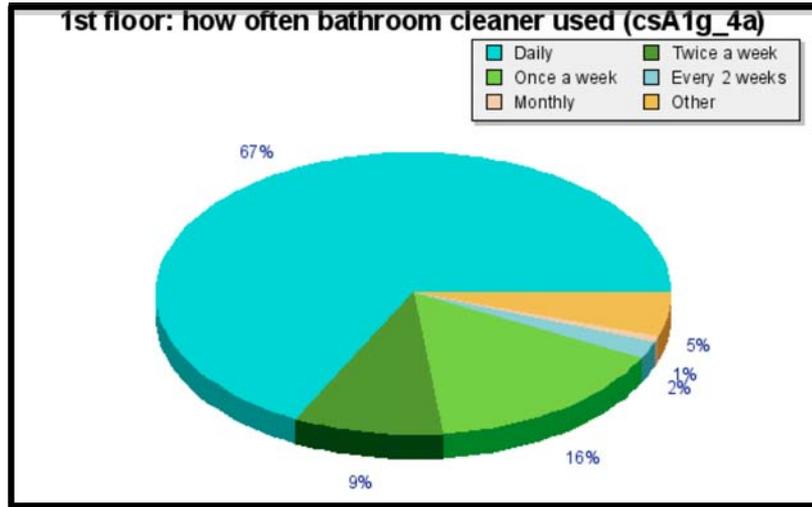
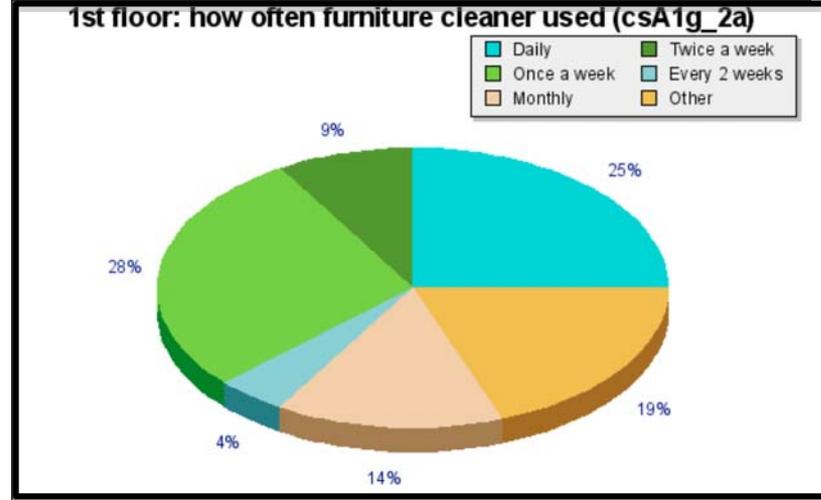
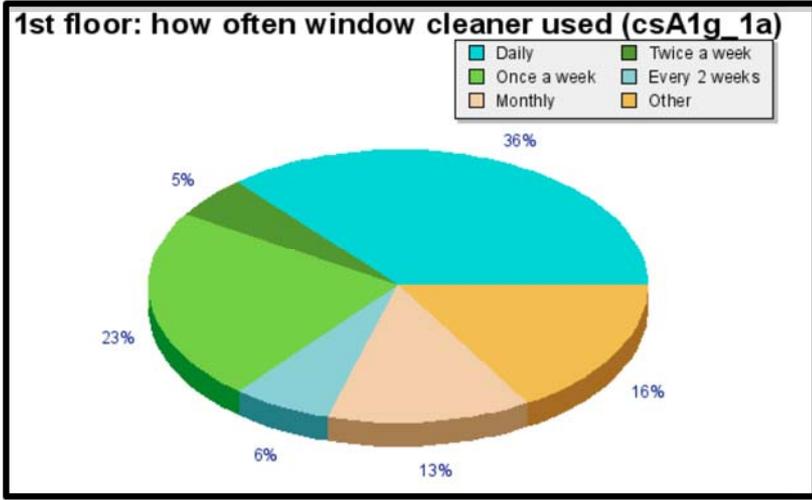


Minimum Outside Air Control



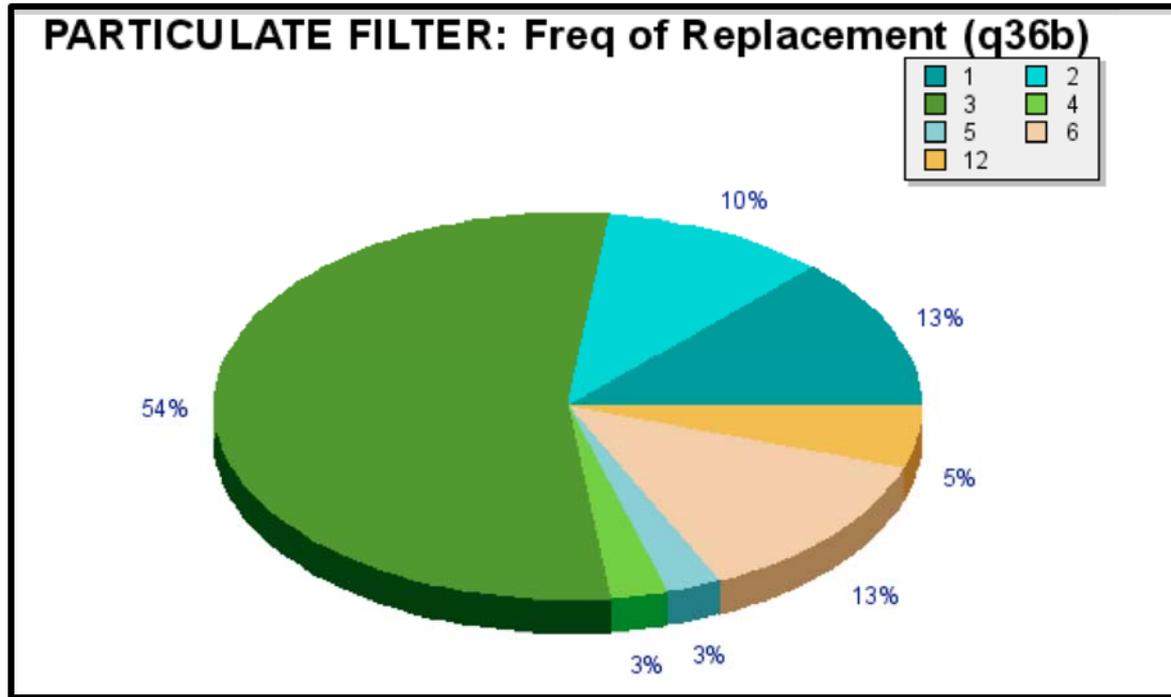


Indoor Cleaning Sources





Filter Maintenance



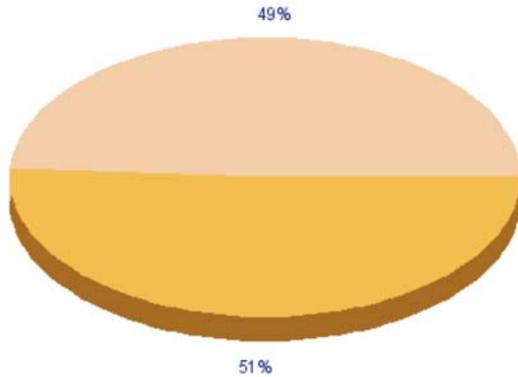


Thermal Conditions



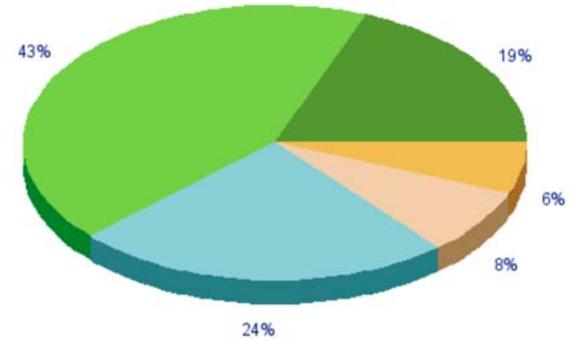
Occupant complaints: too hot (oc1_a)

No Yes



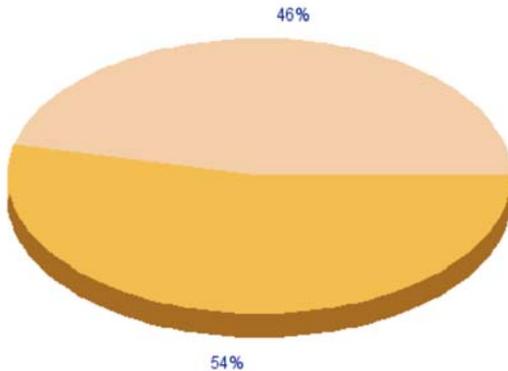
Occupant complaints: how often too hot (oc1_a1)

Once or twice Not very often
Somewhat often Very often
Constantly



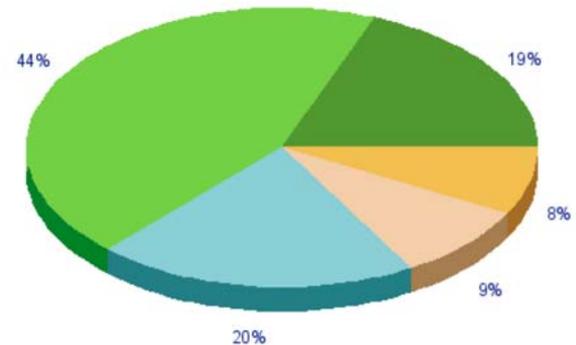
Occupant complaints: too cold (oc1_b)

No Yes



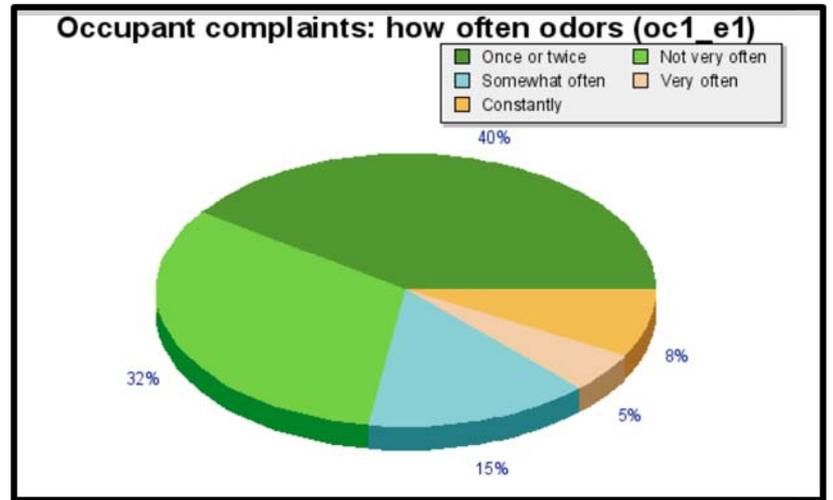
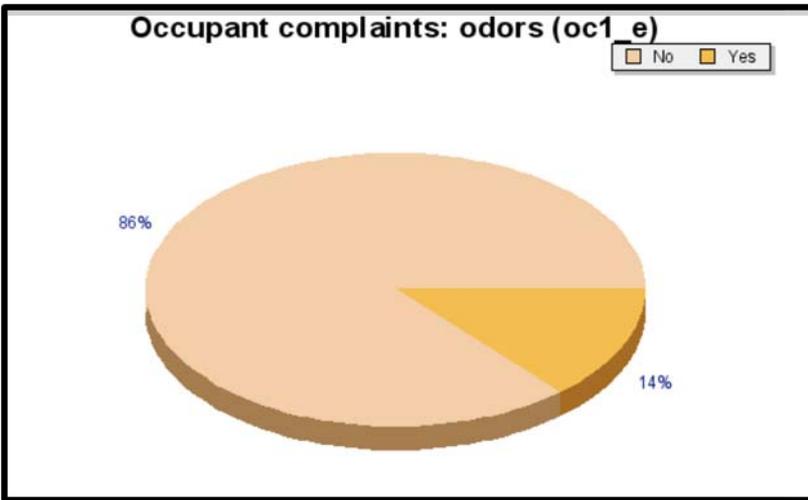
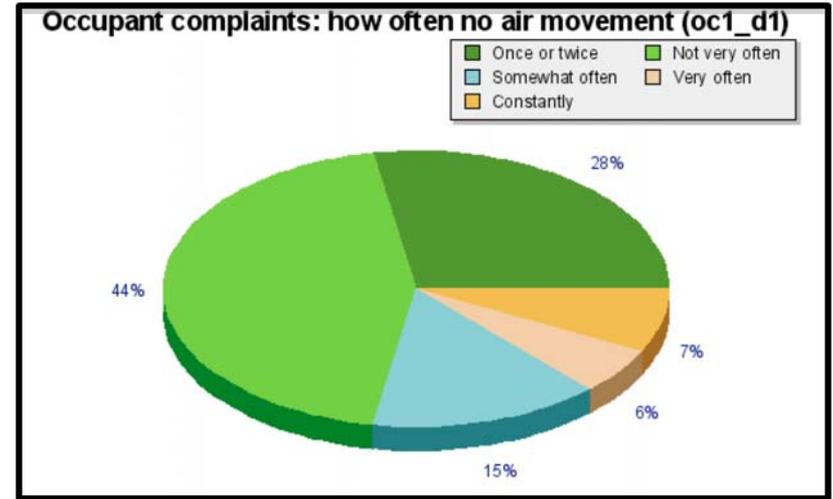
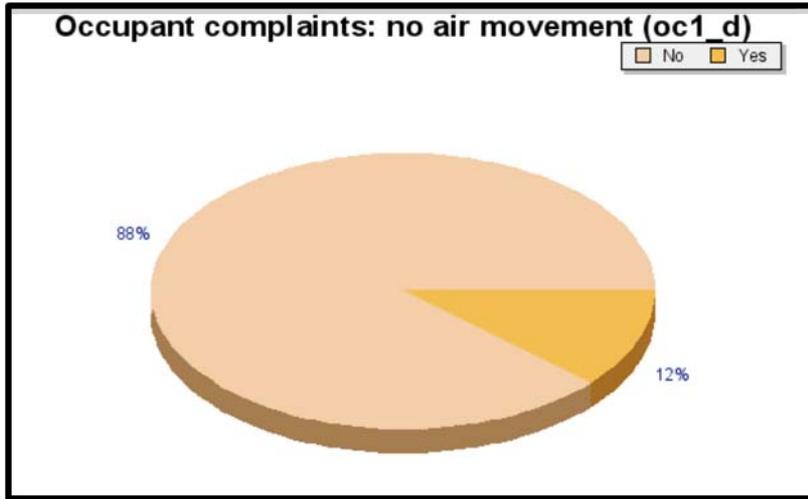
Occupant complaints: how often too cold (oc1_b1)

Once or twice Not very often
Somewhat often Very often
Constantly





Complaints



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



Objectives Met...



- **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
 - 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