to reflect a level that would be expected at the previously described ASHRAE minimum recommended ventilation rate of 20 cfm outdoor air/person. The third target, 1,400 ppm, was selected to represent a higher, but not uncommon, concentration of CO_2 found in indoor environments [1,400 ppm is the maximum observed 8-hr time-weighted-average CO_2 concentration in the U.S. Environmental Protection Agency (EPA) BASE data set (U.S. EPA 1998)]. On Days 2 and 3, when the independent effects of CO_2 were tested, CO_2 was added from a cylinder of ultra-pure CO_2 (≥ 99.9999% pure) to the TIEQ Lab supply air at a rate needed to maintain steady-state CO_2 concentrations of 945 ppm and 1,400 ppm. Because CO_2 concentrations are affected by occupancy and mixing impact concentrations, a technician monitored CO_2 in real time and adjusted the emission rate accordingly to maintain constant CO_2 concentrations. During Days 4 and 5 (Green and Conventional), injection of pure CO_2 was not needed to reach the target CO_2 concentrations because of the reduced outdoor ventilation rate. A protocol was established to ensure participant safety in the event that there were unexpected deviations. CO_2 was monitored in real time at a high spatial resolution in the test rooms using three different and independently calibrated monitors. A technician seated next to the CO_2 shut-off valves monitored the CO_2 concentrations during the entire test period. The protocol called for immediately canceling the testing if CO_2 concentrations exceeded preset thresholds that were well below occupational health limits [2,500 ppm, one-half of the threshold limit value set by the American Conference of Governmental Industrial Hygienists (ACGIH 2015)]. No deviations from protocol occurred during the study.

The TIEQ Lab was constructed with low-VOC materials, and low levels of VOCs were confirmed by pretesting (Table 3). To simulate a conventional office space with elevated VOCs, we placed VOC sources in the diffuser that supplied air to each cubicle area before the participants arrived on Day 5. We selected a target total VOC (TVOC) level of 500 μg/m^3 based on the LEED® Indoor Air Quality Assessment credit limit, as measured using U.S. EPA method TO-15 (USGBC 2014). The diffusers were built into the floor of the TIEQ Lab, and there were no visible indicators of these sources for the participants to observe. We selected a mix of nonodoriferous sources to simulate VOC-emitting materials that are commonly found in office buildings and that covered four indoor VOC source categories including building materials [56 in^2 (360 cm^2) exposed edge melamine, 56 in^2 (360 cm^2) exposed edge particle board, 64 in^2 (415 cm^2) vinyl mat], adhesives [80 in^2 (520 cm^2) duct tape, 80 in^2 (520 cm^2) packing tape (exposed)], cleaning products [1 oz. (30 mL) multi-surface cleaner, 4 multi-surface wipes, 144 in^2 (930 cm^2) recently dry-cleaned cloth], and office supplies (4 dry erase markers, 1 open bottle of correction fluid).

Environmental Monitoring

The study team characterized the TIEQ Lab on each test day for a wide range of IEQ indicators: CO_2, temperature, relative humidity, barometric pressure, sound levels, VOCs, aldehydes, nitrogen dioxide (NO_2), ozone (O_3), particulate matter ≤ 2.5 μm in diameter ($PM_{2.5}$), and light. Netatmo Weather Stations were installed in each cubicle to measure temperature, humidity, carbon dioxide concentrations (parts per million), and sound levels (decibels) every 5 min for each participant. The stations were calibrated to 0 and 3,000 ppm CO_2 using calibration gases and were validated using a calibrated TSI Q-Trak (model 7575). In addition, the Netatmos were tested with 400 and 1,000 ppm calibration gas at the end of the study to determine if the sensors drifted during the 2-week period. Duplicate measures of CO_2 were collected in each room using a TSI Q-Trak model 7575 and two K-33 data loggers. Summa canisters were used to detect overall levels of 62 common VOCs in a randomly selected workstation in each room for each of the study days (Table 3). An additional sample was collected in a third randomly selected cubicle each day. Samples were analyzed by ALS Laboratories according to U.S. EPA method TO-15 (U.S. EPA 1999). Thirty-six VOCs were not detected in any of the samples.

In each room, a monitoring station was placed at the far end of the room from the entrance to monitor additional IEQ parameters. The station included *a*) a TSI SidePak AM510 personal aerosol monitor to measure $PM_{2.5}$, *b*) an integrated filter sample for gravimetric analysis of $PM_{2.5}$ and elemental composition, *c*) an 8-hr integrated active air sample (0.4 L/min flow rate) analyzed for 14 aldehydes by ALS Analytical Laboratories using U.S. EPA method TO-11 (U.S. EPA 1999), *d*) a passive NO_2 badge [8-hr time-weighted average; model X-595, Assay Technology; Occupational Safety and Health Administration (OSHA) method 182 (OSHA 1991)], *e*) a passive sampling badge for O_3 [8-hr time-weighted average; model X-586, Assay Technology; OSHA Method 214 (OSHA 2008)], and *f*) illuminance and irradiance measures using an IL1400 radiometer/powermeter with SEL-033/Y/W and SEL-033/F/W detectors. VOC, aldehyde, NO_2, O_3, and integrated $PM_{2.5}$ samples had at least one blank and one duplicate for every

Table 2. Average indoor environmental conditions simulated in each room of the TIEQ lab.

Variable	Day 1 Green+		Day 2 Moderate CO_2		Day 3 High CO_2		Day 4 Green		Day 5 Conventional		Day 6 Green+	
Date	4 November		5 November		6 November		11 November		12 November		13 November	
Day of the week	Tuesday		Wednesday		Thursday		Tuesday		Wednesday		Thursday	
Room	502	503	502	503	502	503	502	503	502	503	502	503
Experimental parameters												
CO_2 (ppm)	563	609	906	962	1,400	1,420	761[b]	726[b]	969	921	486	488
Outdoor air ventilation (cfm/person)[a]	40	40	40	40	40	40	20	20	20	20	40	40
TVOCs (μg/m^3)	43.4	38.5	38.2	28.6	32.2	29.8	48.5	43.5	506	666	55.8	14.9
Other environmental parameters												
Temperature (°C)	23.9	24.5	22.4	23.9	21.3	22.0	22.9	23.7	21.8	22.5	20.7	21.3
Relative humidity (%)	31.0	30.4	34.2	31.6	38.7	38.3	34.3	33.3	39.6	38.3	27.8	26.8
NO_2 (μg/m^3)	57.9	58.9	53.2	54.1	60.8	58.4	51.3	45.6	54.6	50.8	56.5	55.5
O_3 (μg/m^3)	3.42	21.2	14.4	13.0	1.37	0.00	6.85	238	1.71	1.37	4.11	6.85
$PM_{2.5}$ (μg/m^3)	2.38	3.49	3.35	2.58	2.97	2.42	1.26	1.83	1.68	1.34	1.26	1.38
Noise (dB)	51.3	49.9	49.7	48.8	52.5	48.8	49.6	48.7	51.1	48.8	50.5	49.2
Illuminance (mV)	2.95	2.70	2.89	2.83	2.31	2.04	3.11	2.93	2.74	2.51	2.39	2.28
Irradiance (mV)	9.07	8.76	9.45	9.37	6.00	6.05	9.90	9.60	8.30	8.14	6.70	6.82

Abbreviations: TIEQ, Total Indoor Environmental Quality; TVOCs, total volatile organic compounds.
[a]A constant air flow rate of 40 cfm/person was maintained on all study days, with 100% outdoor air used on days 1, 2, 3, and 6 and 50% outdoor air and 50% recirculated air used to achieve an outdoor air ventilation rate of 20 cfm/person on days 4 and 5. [b]Average concentration from 1400 to 1700 hours was 926 ppm, but lower CO_2 concentrations in the morning hours during the approach to steady state led to a lower average CO_2 concentration.