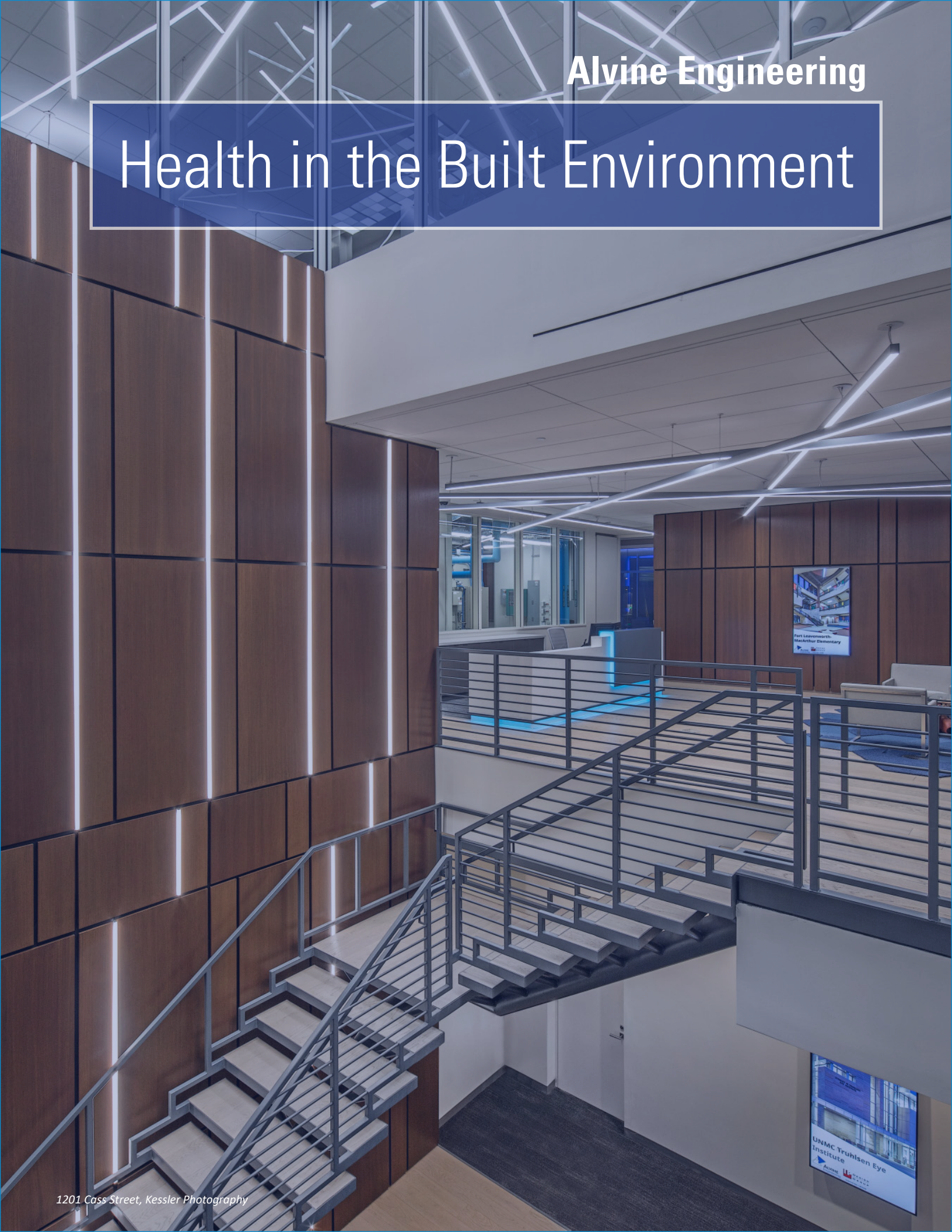
Alvine Engineering

Health in the Built Environment



1201 Cass Street, Kessler Photography

Northwestern Mutual Corporate Headquarters, Rossiter Photography

Foundational Data

Our health is impacted most by the environment where we have the most exposure. We spend upwards of 90% of our time indoors. People living in the developed, modern economy are an indoor species. We live in the built environment. [1]

Eloquently defined by Jones Lang LaSalle, a general real estate rule-of-thumb is that a company will spend $300 per square foot on employee costs, $30 per square foot on rental costs, and $3 per square foot on energy costs.[2] A 2% energy efficiency improvement would result in savings of $0.06 per square foot, but a 2% improvement in productivity would result in $6 per square foot through increased employee performance. As beneficial as energy savings can be, an investment that increases employee wellness and productivity can have exponentially greater value.

"Americans spend more time inside buildings than some whale species spend underwater."

- Rich Corsi
Dean of Engineering and Computer Science at Portland State University

Healthy buildings are not simply buildings that mitigate a specific disease; healthy buildings are a holistic approach to the built environment that enhance human wellness and performance and as a result, business performance.

Improving human performance has the potential for a far greater return on investment than simply reducing energy consumption. Designing with a focus on health and wellness does not require elaborate system designs, unproven strategies, and deep pockets. Implementing strategies can be simple and straight forward.

Research is ongoing and while benefits of some strategies are clear, consensus on other strategies are still forming. These actionable and foundational strategies have a positive impact on the indoor built environment and the occupants in that environment; however, these strategies are not all-encompassing of strategies that improve health and wellness.

Strategies such as nutrition, access to food, shift-work schedules, connectivity to the community/parks, access to the outdoors are all beneficial, but are simply outside the intent of this document.

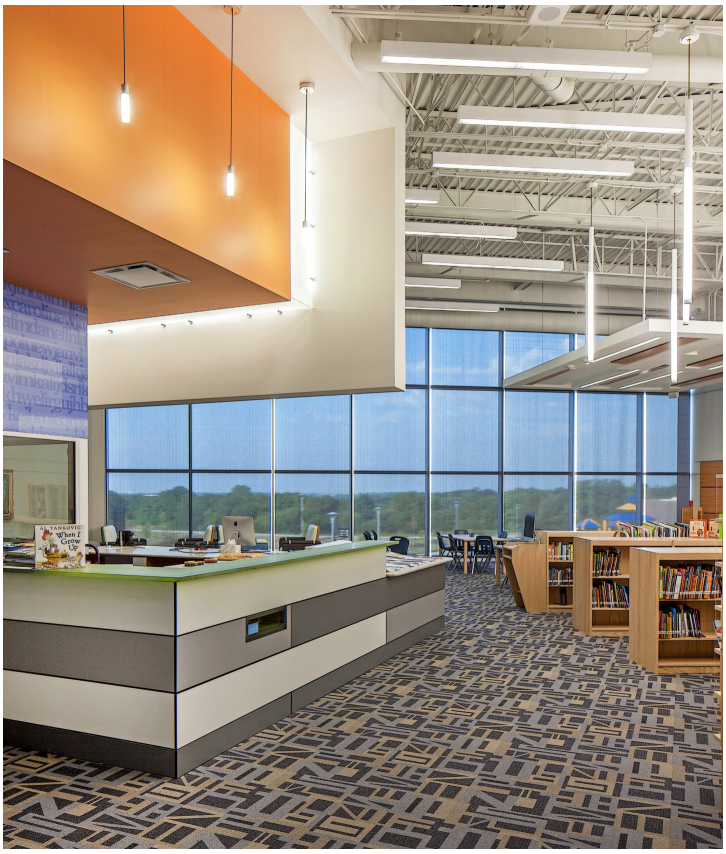
1 Allen et al, 2020
2 JLL, 2016

The Air We Breathe

A building, just like us, must breathe in fresh, outdoor air and exhale the used, old air. This is ventilation; the introduction of outdoor air for controlling air contaminant levels. There is so much research documenting the benefits of adequate ventilation that if only one strategy is implemented; implement better ventilation. For instance, studies on educational facilities have shown that students show a 5% decrease in "power of attention" in poorly ventilated classrooms and that higher ventilation rates are attributed to higher math, reading, and science scores. [1]

The World Health Organization (WHO) has declared that healthy indoor air is a fundamental human right. Looking at this statement through the lens of an 'indoor species,' this claim has substance. Without a doubt, there has been an emphasis on improving outdoor air quality, cutting back on carbon fuel sources, and minimizing greenhouse gas emissions. Yet before COVID-19, there was little coverage on the need for eliminating indoor air pollutants, yet we spend most of our time indoors.

1 Coley et al, 2007



Omaha Public Schools Gateway Elementary, Kessler Photography

Air Management

The location of the outdoor air intake determines the initial quality of air brought into the building. If aesthetics or ease of coordination with architectural programming drives the location of the outdoor air intake, there is the potential that there will be an adverse effect on the indoor environment. Often the outdoor air intake ends up out of sight. When determining the location of the outdoor air intake consider idling vehicles, passenger drop off and pick up zones, exhaust air from neighboring buildings, prevailing wind patterns, and possible locations for secondhand smoke.

ASHRAE 62.1 defines the minimum required levels for ventilation; please note this is the 'minimum' not specifically the 'optimal' level of ventilation. A study by the *National Library of Medicine* called, "The effects of outdoor air supply rate in an office on perceived air quality, sick building syndrome (SBS) symptoms and productivity," showed productivity gains from 2-10% as a result of increased ventilation rates.[1] A University of Maryland research study called, "A Study of Indoor Carbon Dioxide Levels and Sick Leave among Office Workers," showed higher ventilation rates resulted in 1.6 fewer days of absenteeism.[2] Simply reducing absenteeism has the opportunity to capture a 1% improvement in productivity. Many studies recommend increasing ASHRAE 62.1 minimum ventilation rates by 50% to 100%, but there are trade offs.

While ventilation rates are commonly identified as a rate per person, the desired effect is an increase in air changes per hour (ACH), or the number of times per hour the air within a given space is replaced with new air. Other methods to increase air changes are to reduce ceiling heights or to permit air in high volume spaces to stratify and focus on replacing the air within the occupant zone.

While the benefits of increased ventilation are clear and documented, careful consideration and understanding of its impact on the project must be fully understood; as doubling the ventilation rate will effectively double duct and shaft sizes, ventilation equipment capacities and the associated energy usage.

1 Wargocki, 2000
2 Myatt et all, 2002

Improve Building Air Quality

According to the United States Environmental Protection Agency (EPA), particulate matter PM2.5, or airborne particles 2.5 microns in size, is one of the most studied air contaminants. Almost 9,000 publications are available on particulate matter at pubmed.ncbi.nlm.nih.gov that have been published in the last 20 years. Particulate matter concentration levels vary widely by location and urban population:

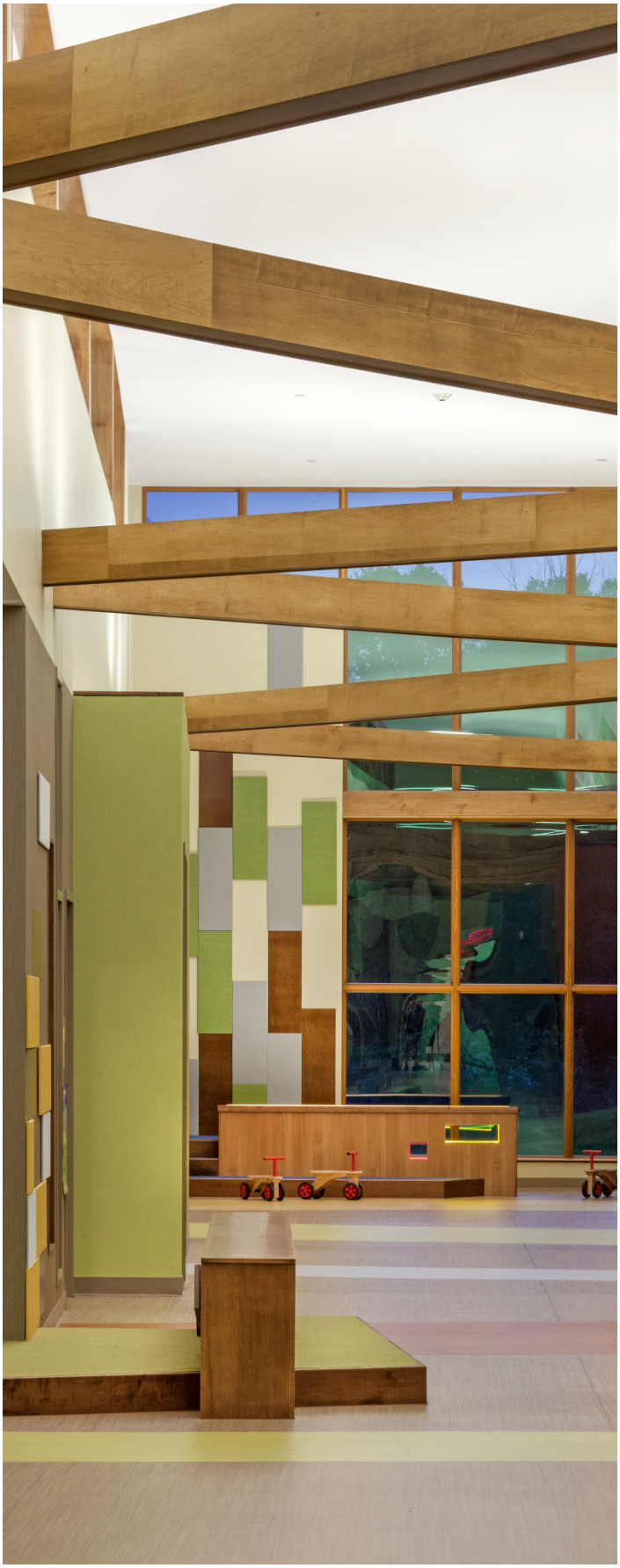
- The United States average = 12 µg/m^3
- Los Angeles = 13-19 µg/m^3
- Major cities in Southeast Asia = 100-500 ug/m^3

Mortality rates within the Medicare population increased by 7% for every 10 µg/m^3 of PM2.5.[1] Hospital admissions increased by more than 4% for every 10 µg/m^3 increase in long-term exposure to PM2.5.[2] Given that outdoor air pollutant varies by geography, the importance of outdoor air filtration is correlated to the building location.

Industry standard MERV 8 filters catch 30% of PM2.5, whereas MERV 13 filters catch 70% of PM2.5.[3] Consider implementing a minimum filtration of MERV 13 to reduce airborne contaminants. For enhanced filtration, MERV 14 or MERV 16 filters, which capture 95% of PM2.5, are recommended. While high MERV rated filters are superior in trapping air contaminants when compared to MERV 8 filters, they do come at the cost of a higher pressure drop. A higher pressure drop may not be achievable within an existing system and it will increase fan energy usage. Increased fan energy usage will increase operating costs. [4]

Omaha Airport Authority Eppley Parking Garage, Hausmann Construction

1 Klogg et al, 2021
2 Di et all, 2018
3 Zhao et al, 2015
4 Bailes, 2014



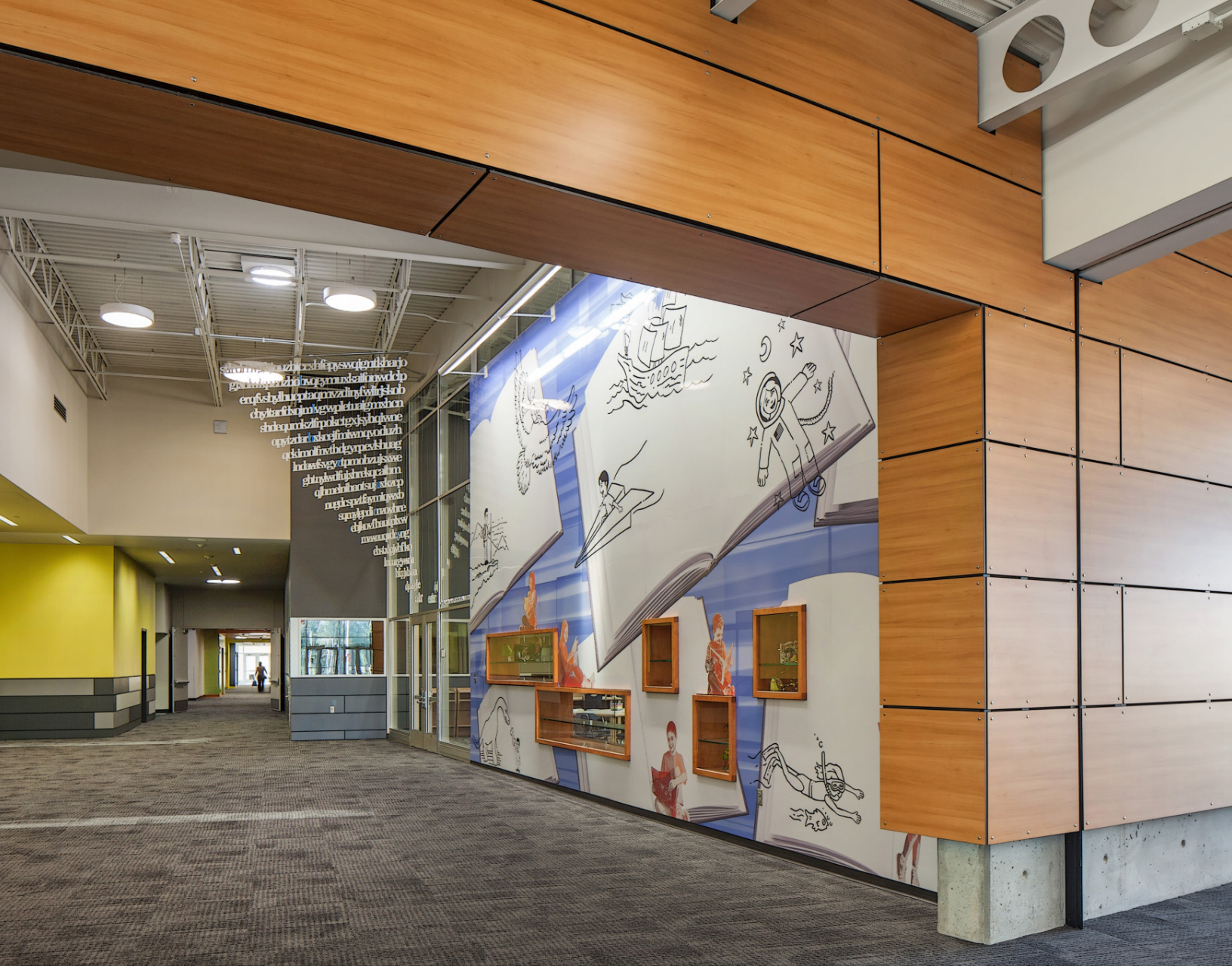
Educare of Winnebago, Kessler Photography

Maintain a Positive Building Pressure

Maintaining a positive building pressure reduces the amount of exterior airborne particles that can enter the building through uncontrolled openings. Turning off the HVAC system results in a loss of positive pressure to the outdoors. This loss of positive pressure in turn, allows outdoor air and its pollutants to find its way into the built environment through unfiltered pathways.

When building HVAC systems must be turned off, or significantly dialed back during off-hours to a point where positive pressure is lost, consider implementing a "flushing" sequence or mode to operate the HVAC system with a maximum outside airflows for, at a minimum, two hours before and after occupied times. Another consideration involves configuring the building automation systems with an emergency or seasonal mode that increases ventilation and exhaust airflows during times of greater indoor air contamination.

Increasing the operational hours of the HVAC system can increase energy costs. At a minimum, avoid or minimize increased energy usage during periods of electric utility peak demand charges. Potentially, pre-clean modes, designed to reduce air contaminant levels ahead of electric utility peak demand charges, could be implemented. Intimate knowledge of the building's electric utility rate structure is essential to understand the resultant impact on energy costs.



Omaha Public Schools Gateway Elementary, Kessler Photography

Control and Eliminate Indoor Air Pollutants

Volatile organic compounds (VOC) are any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions.[1] Select materials and finishes with low-VOC or no-VOC materials. Avoid scented sprays and cleaning agents with high VOC content. Strive for indoor VOC levels less than 50 µg/m^3. Selecting green-certified product is a good first step, but due to the many various options available, companies may use a formaldehyde-free product that contains other aldehyde chemicals used as a replacement to formaldehyde.

1 United States Environmental Protection Agency. 2018

Scrub the Air

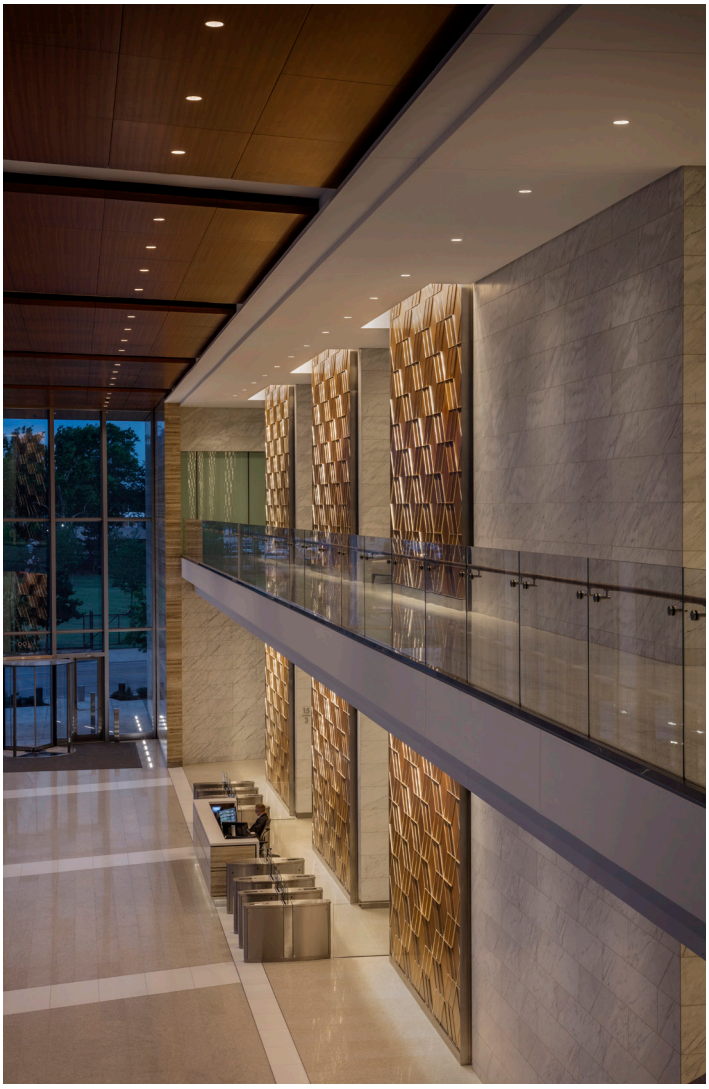
A research study published in the *Journal of American Medical Association Pediatrics 171* published an article called, "Association between allergen Exposure in Inner-City Schools and Asthma Morbidity among students," found the presence of mouse allergens in 99.5% of samples taken from 300 inner city students.[1] Dust consists of dust mites, dead human skin, dog/cat saliva and dander, rodent feces, lead from lead-based paints, and dirt from outside, among other sources. Numerous indoor air pollutants —dust mites, mold, pet dander, environmental tobacco smoke, cockroach allergens, particulate matter, and others—are all asthma and allergy triggers.[2]

A long-standing recommendation from the early versions of LEED is to install walk-off mats. Walk-off mats capture a large quantity of the dust and dirt brought into buildings from people's footwear; thereby reducing airborne contaminants, but must be routinely cleaned.

Maximizing efficiency of filters in the HVAC system is a prerequisite for controlling dust, but ultraviolet (UV) and ionization technologies enhance the ability to capture or inactivate additional airborne particles. UV and ionization systems can be added to most existing building HVAC systems or new designs, but must be balanced with the first cost and operating cost of these add-ons with their short and long term value add to the building.

Ionization systems consist of multiple technologies; but needle point bipolar ionization appears to have the lowest side effects and can be easily added to most systems. The technology works by adding ions to the air that bind particles together, making them larger and easier to capture in filters. This technology will reduce airborne particles and odors; in addition it will kill mold, bacteria, and virus. Specific to COVID-19; needlepoint bipolar ionization has been shown to inactivate 99.4% of the SARS-CoV-2 surface strain within 30 minutes.[3]

Ultraviolet for air disinfection has been available for many years and if the amount of UV intensity required can be achieved and if the air stream can be slowed to the appropriate velocity this system can reduce the amount of viruses in the occupied space.



Bank of Oklahoma Park Plaza, Aker Imaging

Most existing systems will struggle to meet the low air velocity targets recommended by manufacturers to provide the UV exposure duration required. The UV intensity can be increased to make up for a small increase in air velocity above the suggested targets.

Ultraviolet can be introduced in the occupied space where HVAC systems cannot be modified or designed to include the UV disinfection, there are multiple technologies available to bring the UV into the space. Examples include portable UV emitting units than can be brought into a room when it is unoccupied. UVDI manufacture a product that includes a self-contained filter, fan, and UV emitter that can changeover the air in a smaller room such as a hotel guestroom. Next generation technologies being developed includes a UV wand that the airline industry plan to adopt to disinfect planes between uses; this will translate into other industries.

1 Sheehan et al, 2017
2 United States Environmental Protection Agency. 2018
3 PR Newswire, 2020

Humidity Control

Maintain indoor space relative humidity levels between 40-60%, which is ideal for occupants. Bacteria and viruses are carried through the air on aerosolized droplets of moisture. Keeping humidity between 40-60% maintains aerosolized droplets at a relative size that can be captured by MERV 13 filters. [1]

This relative humidity range maintains larger aerosolized droplets within the air. Larger droplets weigh more, thereby reducing the time and distance droplets are airborne. This effectively reduces the opportunity for the contaminants carried through the air on water droplets contaminants attached to the aerosolized to be inhaled by building occupants.

Research has shown that when exposed to low humidity levels, our mucous production is reduced. Mucous is our body's filtration. Lower production of mucous results in a lower capture rate within the breathing pathway; thus we are more susceptible to contaminants on vaporized water droplets.

For buildings in climates with cold winter temperatures, adding humidification can carry a high first cost and operating cost. When implementing humidity controls within colder climates, consideration of building materials and thermal insulation values at exterior walls and windows is required to prevent condensation and potential mold growth in wall cavities that is possible when humidity exceeds 30% in a cold climate.

Continuously Monitor the Air

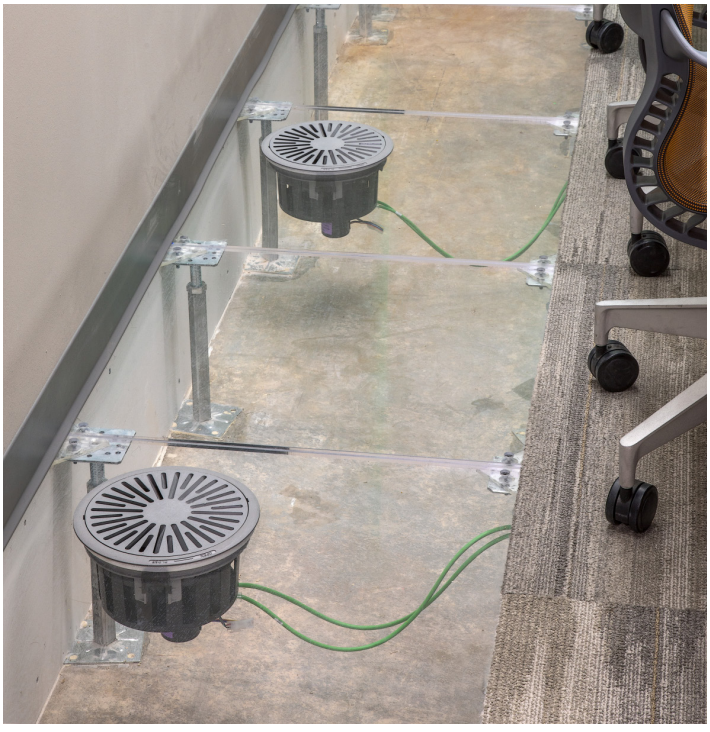
Verify indoor air quality through real-time, continuous monitoring of carbon dioxide, temperature, humidity, and air particulate count. Many offices see carbon dioxide creep above 1,000 ppm, which is the maximum level recommended by ASHRAE. One strategy, called demand control ventilation, monitors carbon dioxide levels, and increases ventilation as needed. Keeping carbon dioxide below 600 ppm is ideal.[2]

System strategies can be developed to increase ventilation and reduce carbon dioxide levels ahead of the electric utility's peak energy usage. This type of strategy would allow energy usage to be curtailed during the time of day that establishes peak demand energy prices.

Continuous monitoring of air contaminants provides a means to provide documented information to building occupants on the overall health of the indoor environment. One third-party benchmarking method that building owners can leverage is The RESET Standard. This relatively new standard, which started in 2013, is a data quality standard explicitly designed for continuous monitoring sensors in the built environment.

If continuous monitoring is not a possible solution for existing system installation or due to project constraints, considering implementing periodic standardized lab testing of air samples. These standardized lab tests can identify the presence of more than 70 VOCs.

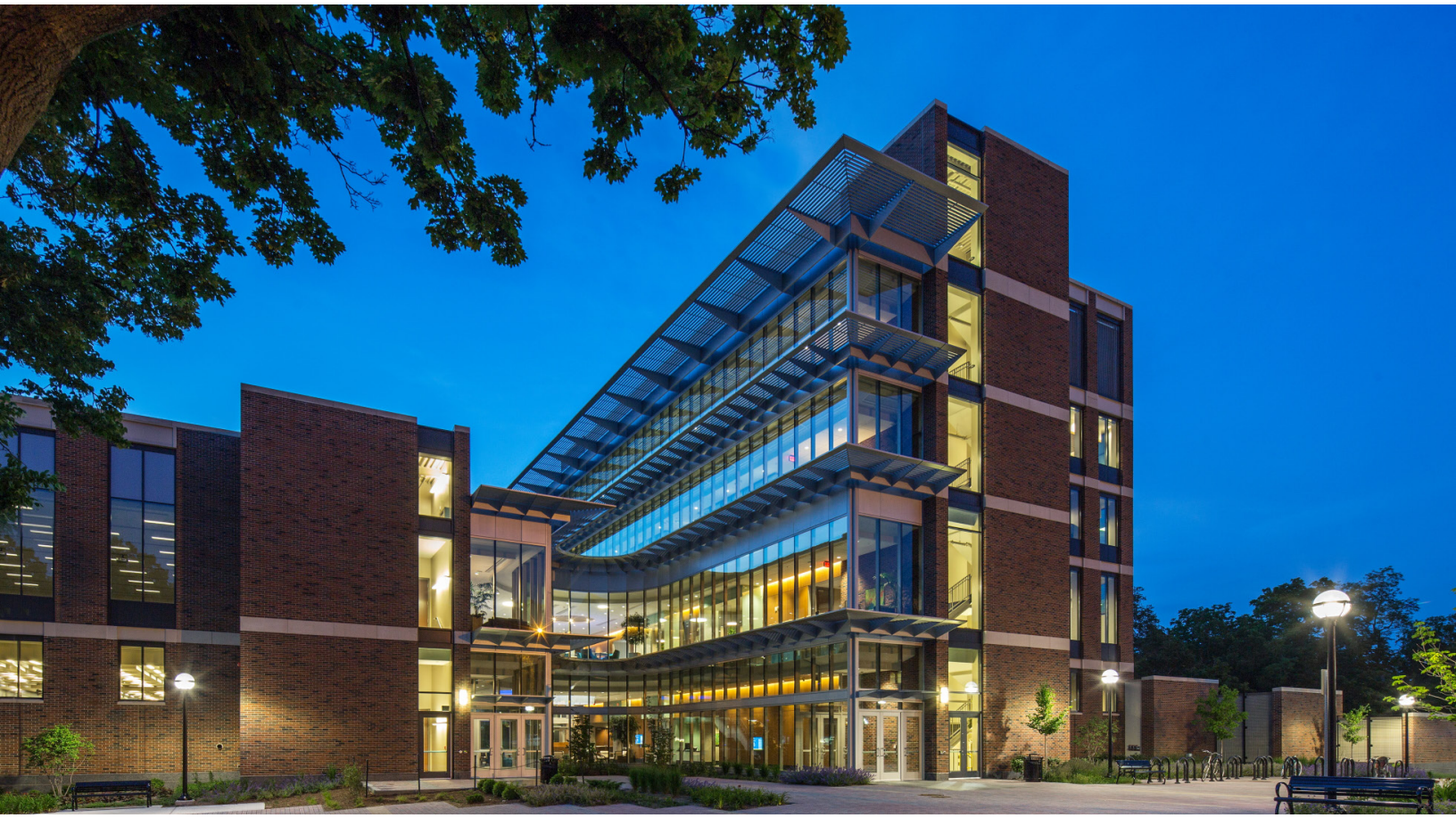
ASHRAE 62.1 is a design standard, not an operational standard. Buildings don't always perform as designed, and buildings will change over time. Continuous commissioning is equivalent to an annual health checkup. For a building owner or operator of an existing building who is concerned about indoor environmental quality, the first step is to confirm the system components that regulate the amount of outside air distributed to the occupied spaces are working as intended.



1201 Cass Street, Kessler Photography

1 Dietz et al, 2020
2 RESET Air, 2020

River Point, ©David Sundberg/Esto



University of Michigan College of Nursing, Kessler Photography

The Light That Shines on Us

Human productivity and emotional health is significantly increased in natural light and connection with the outdoors. Natural light provides necessary vitamins and is foundational to our circadian rhythms which significantly influences our productivity

Daylight

Create areas with high amounts of well-controlled daylight and direct views to the outdoors. In one study, office workers with windows received 173% more white light exposure during work hours and slept an average of forty-six minutes more per night than workers without windows. Workers without windows reported poorer scores on physical problems and vitality, overall sleep quality, sleep efficiency and sleep disturbances, and daytime dysfunction.[1]

A study at Northwest University identified a correlation between sick leave and 'view quality and daylighting' which explained 6.5% of the variance in sick leave. In essence, access to daylight and high-quality exterior views reduced sick leave absences. The penetration of meaningful, high-intensity daylight into an interior space is quite minimal, as daylight typically only reaches into a space about 1.5 times the height of the window fenestrations.[2]

Study facade orientation and space planning to promote access to high levels of daylight during the day, and encourage people to get outside for periods of time.

1 Paul, 2014
2 Elzeyadi, 2011

Induce Our Circadian Response

Several research studies have shown that light is the most potent cue used by most organisms (humans included) to synchronize daily activities. Discovered 20 years ago, our eyes contain blue-sensitive photoreceptors. These photoreceptors are called intrinsically photosensitive retinal ganglion cells (ipRGCs). The peak sensitivity range for ipRGCs is within a range of 460-500nm wavelength. Color spectrum and the associated response by ipRGCs lead to the regulation of our circadian rhythm, known as our 24-hour body clock. We need the presence of high levels of blue light during the day with the absence of blue light at night to keep our circadian rhythm in sync. [1] Understanding spectral power distribution curves and the resultant color spectrum of light sources is of utmost importance.

Due to the current modern built environment, building occupants are generally exposed to intensities of blue-enriched, white light that are 4-13 times lower during the day and 35-45 times higher during the night than what's ideal for our circadian rhythm. The non-visual impact lighting in the built environment has on occupants is profound, resulting in an occupant's internal body clock being out of sync with their daily routine, which has been shown to have a negative impact on mood, weight, attention, and productivity: [2]

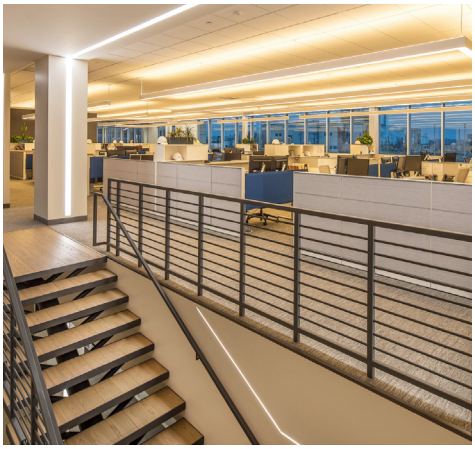
- Wakefulness and sleep-promoting centers of the brain
- Endocrine physiology (Insulin resistant, obesity, and Type 2 Diabetes
- Regulation of core body temperature (Thermoregulation)
- Melatonin levels

Dr. David Blask at Tulane University has published groundbreaking research that shows high levels of melatonin suppress the growth of cancer cells; whereas, low levels of melatonin promote cancer cell growth. Young female nurses who work night shifts have a 60% higher likelihood of developing breast cancer.[3] Countries in Europe have begun to identify night shift work as a carcinogen and are compensating individuals for the long-term adverse health impacts.

While these impacts are known, research is ongoing to develop a consensus to quantify the intensity, duration, color spectrum, and timing necessary to have a positive impact. Until consistent quantitative metrics are developed in the research and design community, designers can select luminaires that have a color spectrum that promotes circadian entrainment. This encompasses lighting designs that incorporate blue-enriched light during the day and when appropriate the absence of blue-enriched light at night. Note designing spaces with 24/7 operations or night shift workers need special consideration.

Bring nature indoors through the implementation of biophilic design with color-tunable lighting that adjusts the indoor electric lighting color temperature to mimic the color temperature variation of the outdoor environment during the course of the day.

1 Bonmati-Carrion, Maria, et al, 2014
2 Hopp, Ph.D., 2019
3 Ruth et al, 2017


The Water We Drink

Know What You Are Serving

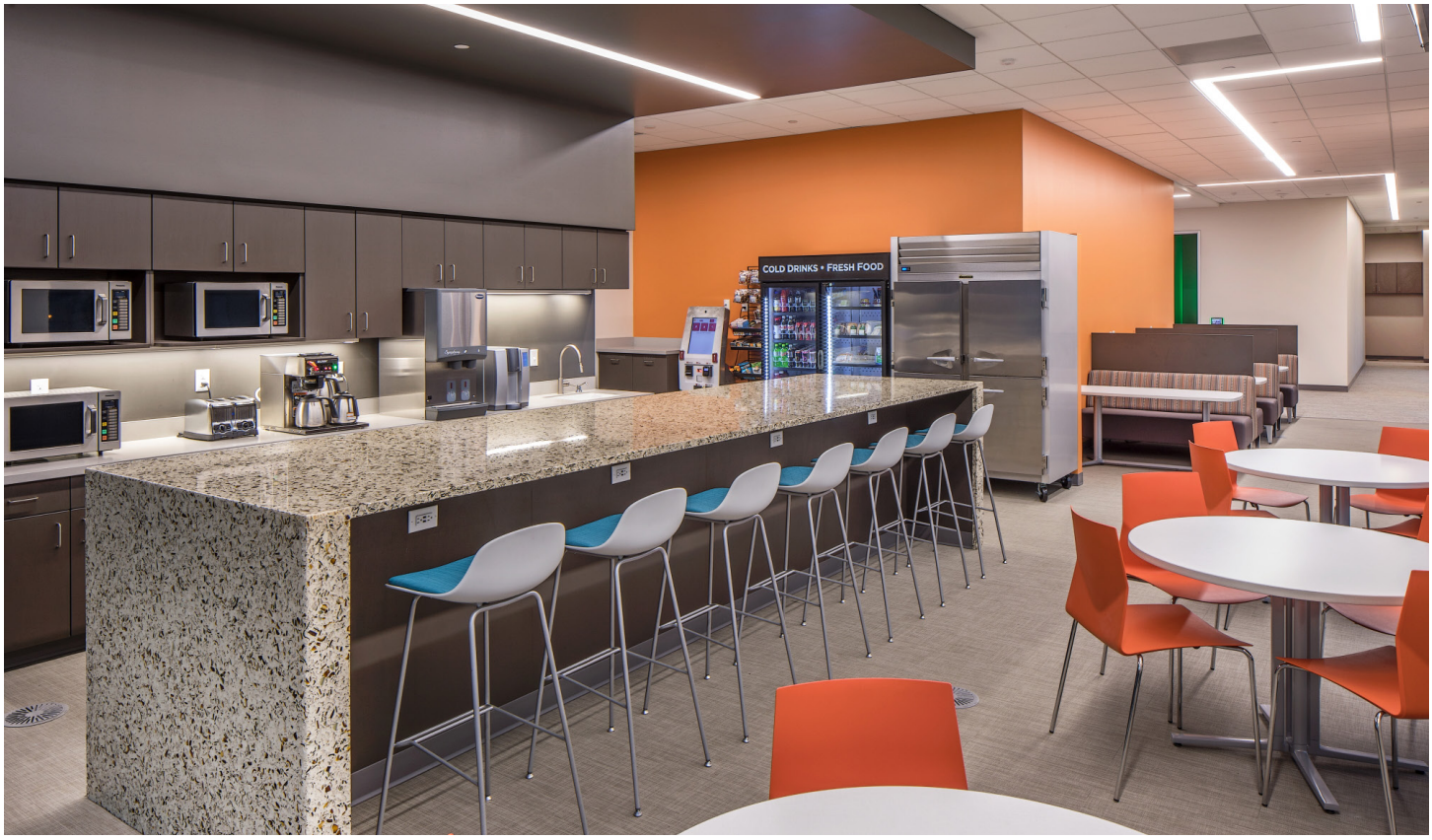
Implement centralized water conditioning systems based upon site specific water profile. Based on the results of the on-site testing, treat and filter the water to the appropriate level based on its use. Drinking water should be treated differently than flushing water. Have periodic standardized lab testing of water samples to test for contaminants, chemicals, and turbidity. The presence of coliform at any level should be avoided and target turbidity levels should be less than 1.0 NTU. The chemicals used by municipal water treatment plant can also remain in the distribution system at levels that are higher than recommended, and if found to be at elevated levels can be filtered from drinking water and other uses as appropriate.

Minimize Water Infiltration

Design building envelope to prevent water infiltration and monitor for leaks. Include leak detection systems monitored by the building management system in locations where leaks are possible or probable. Select materials that are resistant to retaining moisture, especially hidden materials that are not easily accessible.

Promote Hydration

Staying hydrated also helps to regulate mood, performance, and thinking. Consider thoughtful placement of hydration stations, including point-of-use water dispensers, within the occupied spaces. Filter and treat the water to enhance the taste, which in turn, will encourage consumption. Hydration has a direct relation to elimination of toxins within humans.



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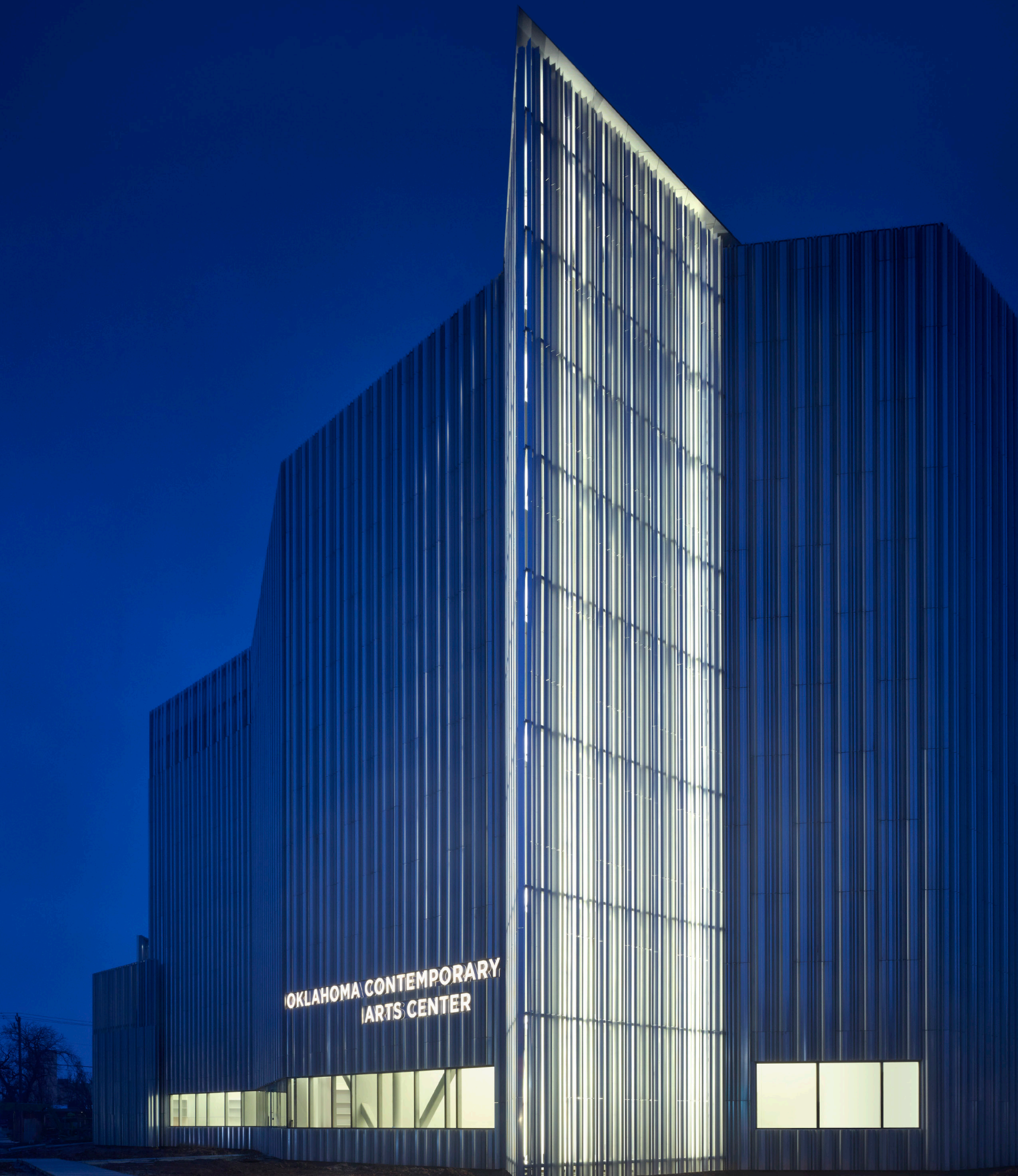
Oklahoma Contemporary Art Museum, Scott D McDonald Gray City Studios



Whole Building Strategies

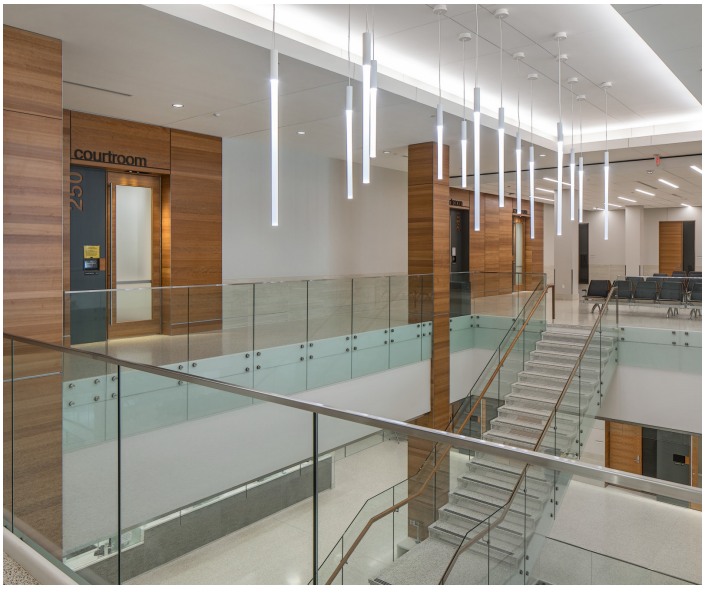
Cortisol is our "fight-or-flight" hormone. When building occupants are in a place that makes them feel safe, cortisol levels go down, stress levels are reduced, and occupants are enabled to focus on the task at hand—the result: improved health and performance.

Frictionless Design

Building entries implemented with touchless automatic openers or revolving doors eliminate a high touch scenario that every building occupant otherwise encounters.

Hands-free plumbing fixtures, towel dispensers, and soap dispensers are simple yet effective ways to improve safety within the restroom. Of note, hand dryers should be avoided as the turbulent, high-velocity air spreads contaminants from individuals' hands throughout the restroom air.

Destination dispatch elevator control is positioned to transform the usage of elevators. This technology has begun to be implemented within buildings over the last several years. Occupants identify the floor they are traveling to, not simply whether they want to go up or down. The elevator system utilizes algorithms to most efficiently distribute elevator cabs to the travelers. Algorithms could be adjusted for unique situations such as the current pandemic, where most elevator capacities have been reduced to four occupants. As technology develops, it is anticipated that occupants will be able to use smartphones or wearables to communicate with the elevator system, creating a completely touchless experience.



Polk County Justice Center, Kessler Photography

Secure Flow

Focus on secure flow, which allows occupants the opportunity to feel safe and secure from arrival to departure. Provide controlled entry points for building occupants. Ensure walking paths to parking areas are monitored so that staff knows they can walk to their cars safely at the end of the day. Secure flow removes the stress induced by the wandering mind of identifying the right time to leave at the end of the day.

Implement rapid screening technologies, such as those developed by Evolv Technologies, combined with employee-recognition systems to improve flow at security checkpoints while decreasing stress. Security checkpoints can be enhanced with thermal imaging to identify individuals with elevated temperatures and initiate appropriate and preventative action. [1]

Self-Cleaning Surfaces

Utilize products for high-touch areas that self-clean at the microscopic level; such as those from Nanoseptic for elevator button covers, hand rails, and walk-off mats. These products utilize mineral nano-crystals that create an oxidation reaction activated by visible light. While these products show promise to address high-touch areas, the surfaces must be routinely cleaned and are recommended to be replaced quarterly.

Currently, there have been paint technologies that have been developed that comply with recommended indoor air pollutant guidelines with VOC less than 50g/L. This technology is EPA-registered and kills 99.9% of pathogenic bacteria within two hours of exposure on a painted surface. [2]

1 Evolv Technology, 2020
2 Sherwin Williams

River Point, ©David Sundberg/Esto

The Path Forward

Utilizing data from the Bureau of Labor and Statistics, a conservative estimate is that 10% of the workforce is knowledgeable of the design and construction of the built environment. This means that 90% of the workforce simply experiences the built environment.

While the COVID-19 pandemic has brought the quality of our indoor environment to the front of everyone's attention, the strategies that positively impact our indoor environment have been around for quite some time. This health movement encompasses more than the built environment, it's all around.

The advancement of technology, particularly sensors in combination with wearables, will transform how building occupants experience the built environment. Apps are being developed to collect human comfort and indoor air quality data. The latest smartwatches track energy monitoring, oxygen saturation levels, stress, hydration, respiration, sleep. Multiple technology brands have partnered together for advanced analytics on data collected from sensors built into wearables. Our core body temperature modulates throughout the day in response to melatonin levels, which is a precise indicator of our sleep-wake cycle.

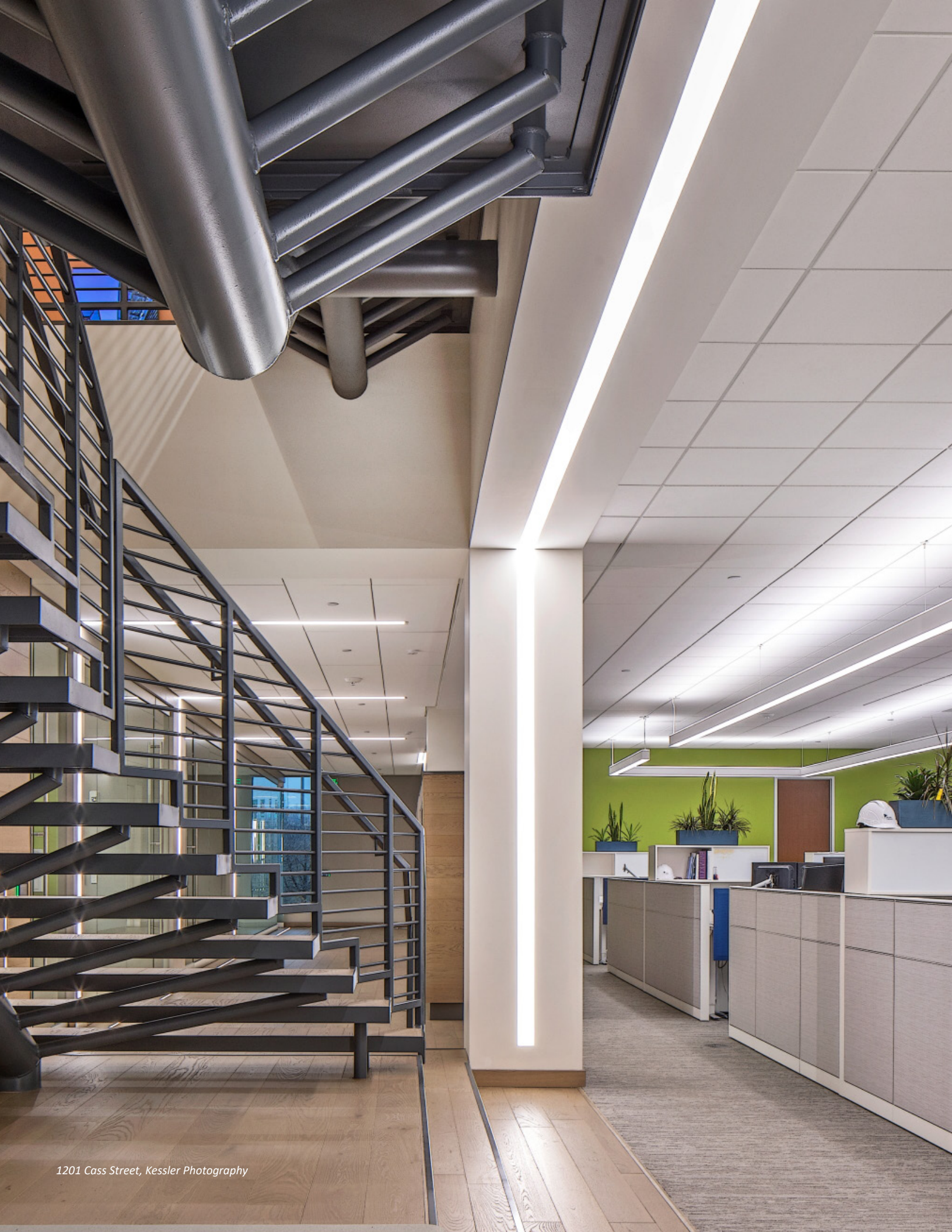
"The built environment is always shaping our health...It is never neutral. It heals us or hurts us...The built environment around us, the buildings we inhabit...They're shaping our health in a myriad of ways"

- Michael Murphy, MASS Design Group

More than 30 types of indoor air monitoring systems are available online. A fairly new tech-based startup is focused on cost-effective continuous air quality monitors for homes and businesses. For $150, a person can buy a counter top solution to track temperature, humidity, CO2, VOCs, and PM2.5 and trend of the data in a smart phone app.

As with most all technology, these sensors will get smaller and cheaper, ultimately ending up in a variety of devices. It is conceivable to project a day where employees have these sensors on their wrist with an app alerting them of the indoor air quality and circadian disruption with peer-to-peer comparisons. The health of the built environment will become a human resource metric.

The strategies presented represent a foundation for making a positive impact on occupant health, wellness, and productivity in the built environment. With most companies offering health and wellness programs as part of benefits packages to its employees, what better program to offer than one that guarantees 100% participation: a healthy built environment.



1201 Cass Street, Kessler Photography

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