Healthy Workplaces for Healthier People

This white paper is the outcome of joint research conducted by GBCI India and Saint Gobain Research India to evaluate the indoor environmental quality of workspaces in India and their impact on occupants’ health and well-being.
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About GBCI India

GBCI is the world’s leading sustainability and health certification and credentialing body. Among other offerings, GBCI is responsible for the market delivery of LEED, the world’s most widely used green building certification program. GBCI provides the framework and process for buildings, homes and other spaces—as well as professionals—to become certified or credentialed under programs that signify sustainable, resilient or health-oriented design. In total, GBCI administers nearly 10 certification and 15 professional credential and certificate programs in addition to LEED that cover sustainable building design, construction and operation; energy and water efficiency in commercial facilities; zero waste; sustainable landscape design; resilient power systems and preparing buildings and communities for acute hazards.

With a presence in 183 countries and territories, GBCI has made LEED the gold-standard for sustainable buildings around the world. As of October 2021, nearly 110,000 commercial projects and nearly 2 million residential units have been LEED registered or certified to LEED.

GBCI India was incorporated in 2016 to facilitate the global growth of GBCI and its sustainability programs and to provide on-the-ground support to the project teams and professionals advancing LEED in the region. The more than 50 technical experts and professionals who make up GBCI India’s core team bring years of subject matter expertise and come from diverse backgrounds, but all share a passion and underlying commitment to being part of the sustainable transformation of the real estate and construction sectors in India.

Visit gbc.i.org/India for more.

GBCI’s corporate head office located in Noida is LEED v4 Platinum certified and sets a benchmark for high performance in sustainability.
**About Saint Gobain Research India**

Saint-Gobain Research India (SGR India) is one of the 8 cross-functional R&D centers for the Saint-Gobain Group that started its operations in 2012. Located within the IIT Madras Research Park at Chennai, the R&D Center is spread over 120,000 square feet and set up with an investment of about Rs.150 crores. With its proximity to IIT Madras, one of the premier academic institutes in India, the center is part of a unique and vibrant ecosystem that fosters innovation through collaboration with academia while partnering with start-up companies. The center supports Saint-Gobain’s existing businesses while enabling creation of new businesses enabling the Group to accelerate its growth and create customized products and services for its customers in India and the region. Since its inception, SGR India’s efforts have contributed to the launch of 97 new products and generation of 100 patents.

To promote customer intimacy and co-creation, SGR India houses pilot lines that are used for research in areas pertaining to new product and process development. The center also has world-class experience centers, which in addition to showcasing advanced products and solutions of the different businesses, also provides customers with a multisensory experience for the living spaces and mobility segments. State-of-art central competency labs that work across all functions support with the structural, physical and chemical testing and characterization of materials required for the development of products, processes and systems.

India is a fast-growing economy that presents unique challenges such as scarcity of resources, need for multi-comfort solutions for hot, humid –and highly luminous climates, large commercial spaces with high people densities, lack of standardization and local practices in construction. To this end, SGR India is currently working towards addressing these unmet needs by transforming its core technologies into innovative solutions by working closely with end customers.

The center is committed to working with the SG India businesses to identify new value creation opportunities and working with the Group’s global R&D network to develop new technologies that can act as future growth engines for India and rest of the world. For the future, while continuing R&D in the areas of core-materials and related technologies, there will also be an increasing focus on sustainability initiatives, digitalization and combinatorial innovation to keep up with India’s fast-growing economy and the constantly transforming environment.

The Center continues to grow and strengthen its already diverse talent pool from various backgrounds in science and engineering, leverage the academic and start-up ecosystem that it is a part of, and work closely with the businesses and their customer to contribute to the development of the Saint-Gobain Group in India and worldwide in terms of new products and processes, of advancement in science and technology and of intellectual property.
Foreword
Mili Majumdar  
Managing Director, Green Business Certification Inc. India

We spend most of our lives inside buildings. As such, the ways they are designed, built and operated have a direct effect on our health, not to mention our overall wellbeing and productivity. The COVID-19 pandemic starkly connected building health and safety with our own. As we continue to deal with the repercussions of this global crisis, the safety standards for our buildings have skyrocketed out of necessity. Businesses must ensure occupant safety by pursuing and maintaining high quality workplaces. Offices have to be spaces where people want to work and where they feel most productive.

The timing couldn’t be better to share the findings of our recent study on the health performance of India’s office buildings, which illuminates the impacts physical surroundings can have on employees. I am hopeful that this study will persuade decision-makers to prioritize workplace health and safety; a people-driven approach to space design and maintenance.

Healthy people in healthy places is the fastest way to build a healthy economy. For organizations to not only survive, but thrive, it is essential that they put people first. Our future lies with sustainable buildings that are centered around the comfort, health and safety needs of their occupants, and India is primed to do exactly that.
Making the world a better home is the purpose on which we at Saint-Gobain have been working with all our stakeholders. Occupier wellbeing and sustainability, during construction and across the building’s lifetime, plays an incredibly important role in living up to this purpose. A fast-growing country like India has the opportunity to chart its economic development and the construction of all of its new built spaces in the most sustainable manner, ensuring comfort and wellbeing for occupants across the nation. It was therefore necessary for us to understand the diverse needs, end uses, climatic conditions, designs and choice of materials to enhance occupant wellbeing and overall sustainability.

GBCI was a natural partner in this exercise given their expertise in this field, range of buildings and geographies covered in their certification practice and more importantly the values both the organizations share. The study was an extensive exercise carried out over a period of three years, with deep data analysis spanning over a year. The results of the study indicate a strong correlation between indoor environmental quality and occupant productivity, health and wellbeing. The results of the study establish that both design and operational excellence are required to achieve high-performance building envelopes that bring value to both upstream stakeholders (investors, builders and developers) and to occupants.

Insights from this study would surely help us in enabling light and sustainable construction, and thereby in our pursuit to make the world a better home.
Buildings interact with the outdoor environment and create the indoor environment where we live, work, learn and play. A healthy building shields us from external contaminants and creates a safe and comfortable indoor space.

When in an enclosed space, we are constantly interacting with the indoor environment. These interactions are complex and dynamic and influence our physical and mental health. The air we breathe, the light we are exposed to, the sounds we hear, the thermal sensations we feel and the views that we are exposed to are all components of our indoor environment. The quality of indoor environment is determined by the design of the space, the systems and materials installed and the operation and maintenance practices followed. Well designed and maintained spaces do not just provide a healthy and comfortable environment, but also enhance occupants’ health and improve productivity.

Despite the importance of a high-quality indoor environment, workspaces rarely receive the kind of attention they require.

This study highlights the correlation between indoor spaces and occupants’ health and well-being. While this conversation is not new, the COVID-19 pandemic has put a spotlight on its importance. When every breath evokes fear, the comfort and safety of shared spaces come under scrutiny. The expectations for workplace environments are destined to change in the post-pandemic world. This study began in 2018, and its findings are more relevant now than ever, bringing to the forefront critical indoor environmental issues that offices in India must tackle.
About the study

This study is a joint effort by GBCI India and Saint Gobain Research India to evaluate the health performance of office buildings across the country, focusing on the indoor environment in buildings and their impact on the people who work in these buildings.

The aim of the study was to address the following questions:

- Are the buildings healthy and comfortable for people to work?
- What are the factors that influence the quality of the indoor environment and avenues for improvement?
- How does the quality of the indoor environment affect the occupants, and how do they perceive their space?
- How office space interventions can improve occupant health and wellbeing?

We studied 30 office spaces located in nine Indian cities covering three major climatic zones of India. The buildings are a mix of green certified and non-certified spaces owned by private and government agencies.

Collectively, the offices had an occupancy of about 30,000 people, 1,500 of whom participated in an online survey that served as part of the study. Survey participants were mostly service sector employees including IT professionals, architects, consultants, accounting, finance and purchasing professionals.

We hope this study helps anyone who is interested in ensuring a healthy environment for themselves, families and colleagues.
Study protocol

The study focused on collecting as much data as available across the following three categories:

1. The design and operational performance of buildings and their systems;
2. Information on occupants’ health and lifestyle; and
3. Occupants’ perception of the space.

We collected data on the area, occupancy, zoning and specifications of envelope; heating, ventilation and air conditioning (HVAC); and lighting system via questionnaires completed by each building’s facility management team. Site visits were made to observe indoor air quality, lighting, thermal and acoustic comfort by conducting spot measurements for various parameters over two days. A standard operating procedure for conducting the measurements and documenting the collected data was established at the beginning of the study.

During these two days, we also conducted a visual inspection of the systems and operational practices followed in the office space. Data on the occupants’ perception and their health and lifestyle was collected through an online survey conducted in each building with support from the administration or human resources departments.

Medical experts were consulted while preparing the survey questions and for vetting the findings of the analysis. No personally identifiable information was captured in the survey to maintain the respondents’ anonymity and encourage them in sharing their feedback about the space without any inhibition.

<table>
<thead>
<tr>
<th>Data Collected</th>
<th>Tools for Data Collection</th>
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<tr>
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<td>From the building’s facility managers via a questionnaire</td>
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<td>• Envelope and interior finishes</td>
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</table>

### Building

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<th>Operation and Maintenance</th>
<th>Perception About the Space</th>
<th>Health and Lifestyle</th>
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<tr>
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<td>• System status</td>
<td>• Perception about indoor environment aspects</td>
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<td>• Envelope and interior finishes</td>
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<td>• Reasons for dissatisfaction (if any)</td>
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<tr>
<td>• HVAC and lighting</td>
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<td>• Operational practices</td>
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</tr>
<tr>
<td>• Acoustic Strategies</td>
<td>• Acoustics</td>
<td></td>
<td>• End of day feeling</td>
<td>• Workplace routine</td>
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</tbody>
</table>

### People

<table>
<thead>
<tr>
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<td>• Workplace routine</td>
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<tr>
<td>• Self-perceived impact on productivity</td>
<td>• Health symptoms</td>
</tr>
</tbody>
</table>
How healthy and comfortable are Indian offices?

The study findings highlight considerable room for improvement in Indian offices when it comes to maintaining a healthy indoor environment. Building managers’ and occupants’ lack of awareness and education of indoor environmental quality (IEQ), inadequate design, poor operation and maintenance practices are the reasons behind poor-quality indoor environments in most offices.

The status of different IEQ parameters was assessed with reference to relevant national and international standards. Reference standards for all the indoor environment factors evaluated to define the workspace quality are listed in the Appendix on Page 30.

### Factors Evaluated to Define Workspace Quality

<table>
<thead>
<tr>
<th>Indoor Air Quality</th>
<th>Lighting Environment</th>
<th>Thermal Comfort</th>
<th>Acoustics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate matter (PM$<em>{2.5}$, PM$</em>{10}$)</td>
<td>Illuminance</td>
<td>Air temperature</td>
<td>Sound pressure level</td>
</tr>
<tr>
<td>Nitrogen dioxide (NO$_2$)</td>
<td>Equivalent melanopic lux</td>
<td>Relative humidity</td>
<td>Reverberation time</td>
</tr>
<tr>
<td>Carbon dioxide (CO$_2$)</td>
<td>Access to good quality external views</td>
<td>Air velocity</td>
<td>Noise criteria</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td></td>
<td>Mean radiant temperature</td>
<td></td>
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<tr>
<td>Formaldehyde (CH$_2$O)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total volatile organic compounds (TVOC)</td>
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</tbody>
</table>

**Indoor air quality**

Since we spend more than 90% of our time indoors, our indoor environment and its systems significantly impact the quality of the air we breathe. Office workers spend roughly one-third of their daily time in the workspace, therefore the quality of air maintained inside office buildings has a significant impact on both their short and long-term health. Refer to the Appendix on Page 30 to see the health impacts of different indoor air pollutants.

**Unhealthy indoor air is common**

The study revealed that most offices are unable to maintain healthy indoor air quality. Out of the 30 offices studied, only one had all the indoor air contaminants within limits prescribed by standards. In 73% of the spaces, the levels of three or more contaminants did not meet the prescribed limits. Both indoor-generated contaminants and those entering from outdoors were a concern due to the adverse impact they have on occupant health. Carbon dioxide (CO$_2$) and nitrogen dioxide (NO$_2$) were the most common non-compliant contaminants indoors, followed by particulate matter (PM) and formaldehyde (CH$_2$O).
Carbon dioxide levels, which are generally used to evaluate the ventilation adequacy of any space, were found to be higher than the recommended threshold of 800 parts per million (ppm) in 75% of the office spaces. Many of the spaces with poor ventilation had formaldehyde levels higher than the recommended threshold level of 30 \( \mu g/m^3 \), as well. Inadequate outdoor air intake results in contaminant build-up inside. Given the COVID-19 pandemic, the role of proper ventilation is being emphasized and correcting insufficient ventilation is critical to ensuring the safety of workspaces.

Elevated levels of \( CO_2 \) have a negative impact on human cognition and decision-making\(^2\). Studies show that \( CO_2 \) concentrations of 1,400 ppm can reduce the basic decision-making ability of humans by 25% and complex strategic thinking by around 50\(^3\).

Despite all but one of the offices in this study having provisions for outdoor air intake, poor operation and maintenance of the ventilation system resulted in elevated levels of \( CO_2 \) and formaldehyde indoors. Poor maintenance of air handling units and filters led to choked air filters resulting in reduced outdoor air intake and high \( CO_2 \) levels. In a few of the offices studied, it was observed that due to high outdoor air pollution levels, the building operators shut off outdoor air intake as a measure to reduce the entry of outdoor pollutants inside the space, unaware of the resulting build-up of indoor pollutants.

Fig. 1: Indoor Air Quality Status in Case Studies

**Poor ventilation equals poor health**

![Graph showing indoor air quality status in case studies](image)

![Graph showing CO₂ levels in ppm in case studies](image)
Study data showed that CO₂ sensor-based outdoor air intake is an effective strategy to ensure proper ventilation. All the spaces with sensors installed correctly in the occupants’ breathing zone were able to maintain desired indoor CO₂ levels. However, there was one office where even with the sensors installed, the CO₂ levels were too high. Site investigation showed that the setpoint of the CO₂ sensors was set incorrectly at a level higher than the recommended threshold.

Are buildings prepared to filter outdoor pollutants?

Outside air plays a critical role in removing indoor air contaminants and improving the air quality in enclosed spaces through ventilation. But when outside air quality is extremely poor, configuring a ventilation strategy to dilute indoor contaminants while controlling external contaminants is essential. Ambient air pollution has become a critical environmental health concern in India over the last few years, and unless buildings are equipped to filter outside air, outdoor air pollutants can enter the spaces unchecked and become the most significant source of indoor air pollution.

Study data showed that 67% of the offices had nitrogen dioxide (NO₂) higher than the recommended threshold. Nitrogen dioxide from outdoor traffic entering through ventilation and infiltration was found to be the most likely cause of higher levels indoors. Chemical filters that can remove NO₂ from outdoor air were found in only 10% of the spaces.

The concentration of particulate matter (PM), which is a major health risk in most urban areas of India, was higher than the threshold in 63% of spaces. 40% of the spaces did not have filters installed to trap fine particulate matter (PM₂.₅), and in around one third of the spaces that did have fine particulate filters, poor maintenance of the filters was an issue.

Performance of fine filters in varying outdoor air pollution

The case study locations and the time of year when the measurements were carried out varied; therefore, the outdoor PM concentrations also varied in each case. This helped in understanding the performance of filtration systems in dealing with fluctuating levels of ambient particulate pollution.

A comparison of outdoor and indoor PM levels for spaces that had filtration systems with fine filters (those with a Minimum Efficiency Reporting Value rating of MERV 13 or above, which by the way have been found effective as a solution to prevent the COVID spread) or electrostatic precipitators was done to evaluate the effectiveness of the system in different outdoor PM level scenarios.
Effectiveness in filtering out coarse particles (PM\textsubscript{10}): A well-maintained system was effective until outdoor PM\textsubscript{10} levels were in the ‘very poor’ category. However, in the case of extremely high outdoor levels in the ‘severe’ category, even though the filtration system was effective in reducing the indoor levels by around 90\% (from 733 µg/m\textsuperscript{3} to 76 µg/m\textsuperscript{3}), it was not able to achieve the indoor PM\textsubscript{10} level of less than 50 µg/m\textsuperscript{3} as per the standard.

Effectiveness in filtering out fine particles (PM\textsubscript{2.5}): Well-maintained systems were effective when outdoor levels were ‘moderately polluted’ (61-90 µg/m\textsuperscript{3}) or lower, but ineffective when outdoor levels were ‘severe’ (250 µg/m\textsuperscript{3} or greater).

These findings show that in locations where outdoor pollution is exceptionally high, additional strategies may be required to keep particulate matter within healthy levels in indoor spaces. Depending on the intensity and duration of high outdoor PM\textsubscript{10} and PM\textsubscript{2.5} levels, outdoor air intake needs to be regulated to optimize indoor and outdoor pollutants and additional filtration technologies should be considered.

**Case Study: Poor operation and maintenance and ignorance led to unhealthy indoor air quality in this space.**

In one case study, we observed that due to very high outdoor PM levels, the ventilation system of the space was shut off by the facilities team. Consequently, the concentration of CO\textsubscript{2} and total volatile organic compounds (TVOC) levels in the space increased, causing discomfort to the occupants. Some occupants opened the windows due to discomfort, which allowed the outdoor pollution to enter indoors unfiltered. The PM\textsubscript{2.5} and PM\textsubscript{10} levels indoors were measured to be six and nine times the threshold, respectively. The facility management team did not realize that it was a significant health hazard for their occupants.

**How do occupants feel about indoor air quality?**

Even though on-site measurements showed that most workspaces had unhealthy air quality, 68\% of the surveyed occupants reported satisfaction with the quality of indoor air. However, 45\% of the survey respondents reported experiencing eye irritation, fatigue, dizziness, coughing and other symptoms which can be attributed to poor indoor air quality.
The fact that high levels of indoor air contaminants were largely unnoticed by occupants indicates how critical it is to educate occupants on the impact poor indoor air quality has on their short and long-term health and the need to constantly monitor it.

Lighting environment and outdoor views

Light has a deep connection with overall human health and well-being and does much more for the human body than just helping us see well. A good lighting environment can help people work more effectively, improve mood, boost energy levels and have a positive impact on overall physical and emotional health. Since lighting quality and views are interrelated and define the overall lighting environment in a space, these were analyzed together. The following parameters were examined to evaluate the lighting environment in the workspaces:

1. Illuminance,
2. Equivalent melanopic lux (EML), and
3. Access to good quality external views.

Poor lighting conditions are common

We found that 64% of the spaces studied had illuminance levels lower than the recommended standard. In fact, in some of the spaces, the lux levels on workstations were lower than 100 lux, which is one-third of the recommended lux level.
A surprising observation in many spaces was that despite low daylight levels, artificial lights were not switched on, and occupants continued to work in poor lighting conditions for most of the day without complaint. In 15 of the 19 spaces with illuminance levels lower than the standard, not all the artificial lights were switched on. Some of these low-illuminance spaces even provided task lights for the occupants, however, they were not being used.

These issues highlight the need for better lighting controls and the integration of lighting sensors to ensure adequate illuminance in workspaces throughout the day.

**Lighting quality: A hidden problem?**

Glare and non-uniform lighting were some of the other issues observed in many of the workspaces. Improper lighting conditions can cause visual discomfort, resulting in health issues like eye strain, dry eyes, blurry vision and headaches.

60% of the survey respondents reported problems related to their eyes. Eye strain was the main problem reported, which is due to low lighting conditions.
Despite poor lighting conditions observed, 76% of occupants reported satisfaction with the lighting. These findings highlight that poor lighting is a hidden issue that is unperceivable by most occupants and is not getting the attention it merits from building designers and operators.

### Circadian lighting

Research shows how light is not limited to helping us see; it has a range of non-visual effects on human body functions. Light affects the human circadian rhythm, which is the body’s internal system that tells us naturally when it is time to wake up in the morning and get sleepy at night. Circadian rhythm controls multiple body functions like our sleep-wake cycle, blood pressure and metabolism - thereby affecting our alertness, digestion, sleep and overall health. The lighting environment to which we are exposed, therefore, has an important role in influencing our overall health.

Exposure to adequate circadian effective lighting during morning hours has been associated with better sleep quality and lower stress amongst office workers. ‘Equivalent melanopic lux’ (EML) is a metric that characterizes circadian light, or light that acts as a stimulus for the human circadian system. The study findings show that only 10% of offices met the recommended level of at least 200 EML during morning hours.

Daylight has the highest level of light to which the human body’s circadian system is most sensitive; however, we observed that most spaces did not have adequate daylight indoors due to design factors like a deep floor plate, placing meeting rooms and cabins in peripheral areas or high partitions. In offices with manually operated blind systems, it was observed that the practice of occupants using blinds to avoid glare was another reason that led to low daylight penetration indoors. Even though the glare from windows was only for a specific duration, once the blinds were down, they stayed closed for the entire day, greatly reducing daylight penetration inside the space.

Only 10% of offices met the equivalent melanopic lux standards during morning hours.
Access to external views is important for people’s health and well-being

Access to quality external views (unobstructed view of sky or open green spaces outside the building) connects occupants to the outdoor natural environment and improves mental health. Nevertheless, study findings show that 74% of occupants surveyed reported no external view or only a poor-quality view from their workstations. The data analysis showed that while occupants were unable to notice low illumination, it was the lack of access to quality views that had a significant impact on how they perceived the overall lighting environment of the space.

Lack of access to quality views is directly related to how occupants feel at the end of the day and their sleep quality. People who reported having a good view of the outdoors had higher energy levels at the end of the day and reported fewer sleep-related problems than those with poor or no views.

These findings indicate the significant role external views play in determining the overall space quality and enhancing the health, particularly the mental health and well-being of people.
Careful planning of interior layouts and well-designed windows with appropriate glazing can provide a high-quality lighting environment by maximizing daylight and access to outdoor views. Design for minimizing glare coupled with correct operation of glare control mechanisms ensures that people receive the full benefits of both available daylight and external views.

**Thermal comfort**

As per the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Standard 55, “thermal comfort is that condition of mind that expresses satisfaction with the thermal environment.” A lack of thermal comfort can cause stress among building occupants and negatively affect their productivity. Four parameters were measured to evaluate the thermal comfort conditions: 1) air temperature, 2) relative humidity, 3) air velocity and 4) mean radiant temperature.

Thermal comfort conditions were found to meet the standard in 75% of the office spaces. Variable air volume systems were found to perform better than constant air volume systems in delivering thermal comfort conditions in compliance with the standard.

Overall, 62% of the occupants reported satisfaction with the thermal conditions. The main reasons reported by occupants for dissatisfaction with the thermal conditions were “Often too cold in winter,” and “Often too warm in summer.”
The problem of no or partial access to HVAC control by occupants

In most buildings, the thermal conditions were controlled centrally by the building management system, and only a few buildings provided complete control to occupants to modify thermal settings. Occupants not having complete control over the temperature set points was one of the key factors causing thermal discomfort. It was observed that in most cases, only the meeting rooms had a thermostat whose setting could be modified by the occupants. However, in open office spaces, the facilities team controlled the thermostat temperature set points. In spaces where occupants could manage the set points, they could only do so partially. For example, they could turn off the system but not turn it back on without the facility team’s intervention. This led to overcooled or undercooled spaces and resulted in occupant discomfort.

Other factors observed that could cause thermal discomfort were uneven airflow levels across the floor in the case of centralized systems, and uneven temperature distribution in open offices spaces where the decentralized systems were not available uniformly across the floor.

Spaces are cooler than what occupants prefer

The predicted mean vote (PMV) distribution showed that 56% of the spaces operated on the cooler side of the comfort zone. However, while analyzing occupants’ perception with respect to thermal comfort conditions, we found that comfort perception improves when buildings are on the warmer side of sensation (positive PMV). Putting it simply, while the occupant’s perception indicated a preference for slightly warmer spaces, many spaces were overcooled. Operating buildings on the warmer side of the comfort zone will not only keep occupants happy but also result in significant energy savings.

Local air velocity control can be effective in improving thermal comfort

With a few exceptions, we observed that local air velocity control, which allows the occupants to control air speed in their local environment, was absent in most buildings. To examine the impact of an increase in air velocity on thermal compliance, a hypothetical exercise was conducted for some of the workstations in the spaces where thermal conditions were not compliant with the standard. We found that for workstations that had air velocity lower than 0.2 m/s, an increase in the air velocity to 0.2 m/s, keeping the operative temperature constant, resulted in thermal conditions in four out of the five non-compliant offices becoming compliant. This increase in air velocity can be achieved through ceiling fans, pedestal fans and other local air flow devices.

Some of the case studies provided local air velocity control through ceiling and pedestal fans.
**Acoustics**

In a workplace, acoustic discomfort is usually attributed to unwanted sounds from external sources like the local traffic or internal sources like HVAC equipment, office equipment, people talking, and lack of acoustic privacy. Three parameters were measured to assess the acoustic comfort in the workspaces:

1. **Sound Pressure Level**: measures the loudness of sound from exterior sources;
2. **Noise Criteria (NC)**: assesses the ambient background noise levels from indoor sources like air conditioning units or other noise emitting office equipment; and
3. **Reverberation Time (RT)**: measures the time required for sound to decay by 60 decibels in enclosed spaces after the source of sound has stopped.

We found that all offices performed well in reducing the outdoor noise, and 77% of the offices had the reverberation time (RT) as per the recommended level. However, interior background noise levels (primarily due to HVAC equipment) were higher than the standard threshold (NC of 35 for open offices and NC of 30 for meeting rooms/private offices) in 73% of the spaces. In many spaces, it was observed that the HVAC equipment was ceiling-suspended in open office areas where people work, or the equipment room was near the workspace without proper noise isolation. The proximity of HVAC equipment and inadequate noise isolation for the equipment room and the ductwork were the main reasons for higher interior noise levels.

Fifty-seven percent of the occupants reported satisfaction with the acoustics conditions. “No acoustic privacy,” and “loud noise” were the reasons reported by those dissatisfied with their space acoustics.

**Role of interior finishes in acoustic comfort**

While analyzing the role of different types of ceiling finishes on RT, we found that ceilings with acoustic tiles performed best in optimizing RT values compared to other types of finishes.
Offices with internal partitions made from drywall exhibited lower measured background noise (noise criterion—NC levels) than those with no partitions or partitions made from other materials like medium density fiberboard (MDF) or other hard surface partitions.

**Indoor environmental quality of green-certified spaces**

While a few green-certified spaces displayed high-quality indoor environment, in most cases, we found that even though certified spaces were designed better, they were unable to deliver a high-quality indoor environment. One of the main reasons behind this gap in design and performance was poor equipment operations and maintenance.

Even though in terms of measured indoor environmental performance, the certified spaces did not fare any better than non-certified spaces, the occupants in certified spaces were happier about their overall office environment and had higher energy levels through and at the end of the day than those in non-certified spaces. This could be due to better indoor environmental design which is an integral component of green building certification. However, for projects to realize the full health benefits of green certification, it is essential that project teams utilize all the critical strategies that lead to a healthy indoor space during the certification process. In addition, appropriate maintenance is the key to ensuring that a building is delivering a healthy indoor environment in the long-term and is performing as intended.

While green building certification is a crucial first step, maintaining a high-quality healthy and comfortable space is a continuous process. Rating programs like Leadership in Energy and Environmental Design (LEED) offer recertification for all occupied and in-use projects that have previously achieved certification to reassure projects that their space is performing at a high level, meet every-changing goals and stay on the cutting edge. Buildings can also leverage simple and data-backed performance platforms like Arc to regularly measure and track and improve their building’s performance.
Can people perceive the indoor environment correctly?

Occupant surveys are usually considered a basis for identifying problem areas and evaluating the quality of the indoor environment. However, this study has demonstrated that critical indoor parameters like air quality and lighting are primarily unnoticeable by occupants. Their perception did not align with the actual measured and observed IEQ status of the space. Despite poor lighting and air quality observed, 76% of people reported satisfaction with lighting and 68% with air quality. This highlights that occupants’ perception does not accurately reflect IEQ performance and regular measurement and monitoring is required to protect occupant health and wellbeing.

To realize the full health benefits of certification, green-certified projects should:

1. Attempt to obtain all critical credits aimed at enhancing IEQ at the certification stage,
2. Ensure regular operation and maintenance, and

Occupyants’ perception alone cannot be the basis for evaluating the IEQ performance of a space and regular measurements and monitoring is critical.
What impacts people the most?

High levels of nitrogen dioxide in the indoor air, lack of access to good outdoor views and low melanopic lux level exposure in morning hours were the top factors affecting people's overall happiness with their office environments. These factors also negatively impacted the productivity of a majority of the occupants. Occupants felt fatigued at the end of the day due to lack of access to good outdoor views, poor thermal comfort conditions and high levels of noise generated indoors due to HVAC and other equipment.

**Lack of access to external views** was the top factor affecting how people felt about their workspaces.

<table>
<thead>
<tr>
<th>Unhappiness with the Office Environment</th>
<th>End of Day Fatigue</th>
<th>Negative Effect on Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main factors linked with people's unhappiness with their office environment were:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Lack of access to good outdoor views and high NO₂ levels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Lower EML levels in the morning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Higher reverberation time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main factors linked with people feeling fatigued at the end of the day:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Lack of access to good outdoor views</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- High levels of indoor background noise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Poor thermal comfort conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupants' reports of office environment impacting productivity in a negative way were higher in offices with:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Lower EML levels in the morning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Lack of access to good outdoor views</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- High NO₂ levels</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Snapshot of people’s health and lifestyle**

One of the critical components of this study was to understand the general trend in occupants’ health, lifestyle and workplace habits by analyzing the data from the online survey taken by 1500 people.

Employees spend a significant part of their hours at their offices. Therefore, the work environment significantly impacts their overall lifestyle and well-being. With careful planning and by taking a human centric approach, employers can design workplaces that boost both the physical and mental health of their employees resulting in improved workplace performance and productivity.

**Reports of lifestyle-related health disorders**

44% of survey respondents reported having one or more lifestyle-related health issue in the past year and 15% reported having more than one health issue. Amongst men, obesity and high blood pressure and amongst women, hormonal imbalances and obesity were the main issues reported. Analysis of the calculated body mass index of all respondents showed that 53% were overweight or obese. 46% of those in the age group 25-34 and 66% in the age group 35-44 were overweight or obese.
Sleep quality

Good sleep is vital for a healthy body and mind. It is recommended that for maintaining good health, adults should get seven or more hours of sleep regularly.

As per the survey data, 71% of respondents reported getting less than seven hours of average daily sleep, and 37% of occupants reported sleep-related problems like difficulty falling asleep and not getting enough restful sleep. Correlating the sleep data with lifestyle disease data showed a link between the two. Lifestyle-related diseases were 23% higher from occupants with sleep-related issues than occupants with no sleep issues. Also, incidence of lifestyle diseases was higher in occupants with sleep duration lesser than 7 hours.

37% of occupants reported that they faced sleep-related problems.

Food habits

Healthy dietary habits are key to maintaining good health, so it was good to see that 84% of the occupants reported having breakfast regularly. Reports of lifestyle diseases were higher from the category that did not have breakfast compared to those who had a regular breakfast habit. However, the daily intake of fresh fruits and vegetables was poor. 66% reported that they rarely consumed fruits or ate only one serving of fruit. 59% reported that they rarely consumed vegetables or ate only one serving of vegetables (raw or lightly cooked) daily. There was a direct correlation between the consumption of fresh fruits and vegetables and lifestyle diseases; people who ate two or more servings of fruits and vegetables daily reported less instances of lifestyle diseases.
In response to a question on healthy food consumption during office hours, 46% of respondents reported that they brought their own healthy food to the office and 42% depend on their office cafeteria and vending machines for their meals. Providing nutritious food and beverage options within office premises can go a long way in increasing nutritional intake of employees during working hours.

People with two or more servings of fruits and vegetables reported less instances of lifestyle diseases. Intake of fresh fruits and vegetables was found to be very low.

**Physical activity**

Adequate physical activity reduces the risk of developing lifestyle diseases and is essential for leading a healthy and happy life. Study data indicated that most of the surveyed people get some form of exercise. 92% of survey respondents reported doing physical exercise, though only 34% reported doing vigorous physical exercise.

It was found that people engaging in vigorous activities had less incidences of lifestyle diseases compared to those who did moderate activities or did not perform any physical activity.

![Fig. 13: Link Between Nature of Physical Activity and Occurrence of Lifestyle Diseases](image-url)
While any form of exercise is beneficial for health, it is essential to educate people on the type and duration of physical activity required for a healthy lifestyle. Employers can support their employees with memberships to gyms or incorporate active design strategies to transform sedentary office environments into healthier spaces.

**Workplace habits**

Sitting for very long hours without adequate breaks can lead to myriad musculoskeletal issues and can increase the risks of other lifestyle-related health disorders like diabetes and heart diseases. Study data revealed that prolonged sitting is prevalent amongst occupants. 64% reported sitting for 8 to 10 hours daily at their workstation, and only 19% took a break every hour. Not surprisingly, 66% of the surveyed occupants reported musculoskeletal issues.

For people with desk-based jobs, it is imperative to reduce sitting time to the extent possible and take a break from sitting every hour to stretch and do some gentle exercises. We also found that even with the availability of ergonomic furniture, prolonged sitting coupled with infrequent breaks resulted in short and long-term musculoskeletal issues and increase in eye health problems like dry eyes and eye irritation.

![Bar chart showing frequency of breaks and musculoskeletal problems](image)

![Bar chart showing daily hours sitting at workstation and musculoskeletal problems](image)

Fig. 14: Correlation Between Prolonged Sitting and Musculoskeletal Issues
Workplace interventions to encourage a healthy lifestyle

There are various workplace interventions that can bring about positive changes to people’s lifestyle and overall well-being.

<table>
<thead>
<tr>
<th>Education</th>
<th>Amenities</th>
<th>Policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Access to information on:</td>
<td>- Designated space for mindful eating and relaxation</td>
<td>- Health camps</td>
</tr>
<tr>
<td>- Healthy diet</td>
<td>- Healthy food and beverage options</td>
<td>- Discourage sale of junk food</td>
</tr>
<tr>
<td>- Recommended physical activity</td>
<td>- Open spaces and walkways to encourage walking</td>
<td>- Incentives to encourage physical fitness</td>
</tr>
<tr>
<td>- Correct sitting posture</td>
<td>- Fitness sessions and sports events</td>
<td>- Encourage a culture of microbreaks at workplace to reduce prolonged uninterrupted sitting time</td>
</tr>
<tr>
<td>- Gentle exercise and stretches to reduce stress on the body from sitting</td>
<td>- Gymnasium and sports facilities</td>
<td></td>
</tr>
<tr>
<td>- Individual counselling sessions from experts</td>
<td>- Ergonomic workstations and sit-stand desk options</td>
<td></td>
</tr>
</tbody>
</table>
Towards better workplaces

In this white paper, we have laid out the status of the indoor environment in Indian workspaces, highlighting areas of concern. Feedback from the surveyed occupants has been presented to share both their perspective on the indoor environment and avenues for improvement to ensure they have a comfortable, safe and healthy workspace.

The study has revealed some of the critical issues prevalent across offices in India that go largely unnoticed by occupants, like poor ventilation and improper lighting conditions. Simple strategies like installing a CO₂ sensor-based outdoor air intake can improve the ventilation of a space. Correlations such as a lack of access to outdoor views with high number of sleep-related problems and/or occupants feeling fatigued by the end of the day highlight opportunities to enhance occupants’ quality of life via the workplace design modifications outlined in this paper.

Change is hard but we need to take a hard look at these changes now. In a post pandemic world, occupants want to be confident that their workspaces are safe and healthy.

We hope this whitepaper helps offices across India to prioritize the evaluation of their indoor environments and take the necessary actions to improve them. This is how we can ensure healthy people in healthy places in a healthy economy.

Steps to maintain a healthy and productive workplace

1. Create awareness on IEQ amongst building managers and occupants

2. Evaluate the space
   - Indoor environment audit
   - Engage with occupants
   - Identify IEQ issues that need improvement
   - Implement corrective actions

3. Regular monitoring of building’s IEQ performance

4. Introduce workplace interventions that encourage a healthy lifestyle for occupants
**Design and operational strategies for maintaining a healthy indoor environment**

Based on the indoor environment evaluation of the 30 offices studied, the following are some design and operational strategies to enable a healthy office environment.

<table>
<thead>
<tr>
<th>Indoor Air Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Conduct air quality assessments for outdoors and indoors and install appropriate filters (coarse, medium, fine, and chemical) based on the resulting assessment.</td>
</tr>
<tr>
<td>• Conduct regular monitoring of indoor air quality.</td>
</tr>
<tr>
<td>• For regions where outdoor pollution is very poor or severe for long durations:</td>
</tr>
<tr>
<td>• Configure ventilation systems to optimize air quality with respect to both indoor and outdoor pollutants. During periods of high outdoor pollution, outdoor air may bring in more pollutants than the filtration system can handle.</td>
</tr>
<tr>
<td>• Consider installing new filtration technologies that mitigate pressure-drop related challenges of mechanical filters and provide higher efficiency particulate filtration.</td>
</tr>
<tr>
<td>• Install additional portable fine filters to achieve healthy indoor air quality in places where the duration of high outdoor pollution is short (few weeks a year).</td>
</tr>
<tr>
<td>• Follow specific maintenance schedules for HVAC systems. Clean and replace filters as per the manufacturer's guidelines.</td>
</tr>
<tr>
<td>• Install CO\textsubscript{2} sensors in the occupants’ breathing zone and control the outdoor air supply.</td>
</tr>
<tr>
<td>• Use low volatile organic compound (VOC) materials and finishes in interior spaces.</td>
</tr>
<tr>
<td>• Avoid use of air fresheners and incense indoors.</td>
</tr>
<tr>
<td>• Install printer and photocopier machines in a separate area away from workstations to minimize continuous exposure of occupants to VOCs.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lighting Environment and Outdoor Views</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Optimize the interior lighting for the tasks being performed by the occupants and maintain illumination levels as per the standard.</td>
</tr>
<tr>
<td>• Provide dimmable or multi-level lighting control and install daylight sensors to automatically turn on the artificial lights when illuminance via daylight is inadequate.</td>
</tr>
<tr>
<td>• Provide automatic or manual glare control mechanisms. In case of a manual system, ensure that the blinds are rolled down only during times when there is glare discomfort.</td>
</tr>
<tr>
<td>• Maximize daylight where possible and design artificial lighting to complement the natural light and provide required equivalent melanopic lux levels.</td>
</tr>
<tr>
<td>• Plan interior layouts and design windows to maximize access to quality external views.</td>
</tr>
</tbody>
</table>
Thermal Comfort

- Provide complete set-point control to occupants.
- Conduct system commissioning and air system balancing for uniform distribution of air.
- Provide local air velocity control.

Acoustics

- For locations where reverberation time/echo are an issue:
  - Install acoustic tiles or perforated gypsum boards as a ceiling finish to reduce the reverberation time or echo in the space.
  - Increase soft finishing surfaces on walls such as hanging baffles and curtains.
- For locations where noise criteria/HVAC background noise are an issue:
  - Install air handling units (AHUs) away from occupant workspaces.
  - Provide adequate noise and vibration insulation for the AHUs and ductworks.
  - Install drywall as an internal partition in open office spaces to absorb the HVAC background noise.
## Appendix: Standards referenced for evaluating different indoor environmental quality parameters in this study

<table>
<thead>
<tr>
<th>Serial. No.</th>
<th>Parameters</th>
<th>Reference Standards</th>
<th>Thresholds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Particulate Matter</td>
<td>Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE) IEQ Std. 2019 – Class A Building</td>
<td>PM$<em>{2.5} &lt; 15 \mu g/m^3$&lt;br&gt;PM$</em>{10} &lt; 50 \mu g/m^3$</td>
</tr>
<tr>
<td>2</td>
<td>Formaldehyde (CH$_2$O)</td>
<td>ISHRAE IEQ Std. 2019 – Class A Building</td>
<td>&lt; 30 µg/m$^3$</td>
</tr>
<tr>
<td>3</td>
<td>Total volatile organic compounds (TVOC)</td>
<td>ISHRAE IEQ Std. 2019 – Class A Building</td>
<td>&lt; 200 µg/m$^3$</td>
</tr>
<tr>
<td>4</td>
<td>Nitrogen dioxide (NO$_2$)</td>
<td>ISHRAE IEQ Std. 2019 – Class A Building</td>
<td>&lt; 40 µg/m$^3$</td>
</tr>
<tr>
<td>5</td>
<td>Carbon monoxide (CO)</td>
<td>ISHRAE IEQ Std. 2019 – Class A Building</td>
<td>&lt; 2 ppm</td>
</tr>
<tr>
<td>6</td>
<td>Carbon dioxide CO$_2$</td>
<td>ISHRAE IEQ Std. 2019 – Class A Building</td>
<td>Ambient + 350 ppm (800 ppm)</td>
</tr>
<tr>
<td>7</td>
<td>Sound Pressure Level</td>
<td>WELL Building Standard Version 1 (WELL v1)</td>
<td>50 A-Weighted Decibels (dBA)</td>
</tr>
<tr>
<td>8</td>
<td>Noise Criteria</td>
<td>ISHRAE IEQ Std. 2019 – Class A Building</td>
<td>Open Office: NC 35&lt;br&gt;Meeting Room/Private Office: NC 30</td>
</tr>
<tr>
<td>9</td>
<td>Reverberation Time</td>
<td>ISHRAE IEQ Std. 2019 – Class A Building</td>
<td>Open Office: &lt; 0.8 sec&lt;br&gt;Conference Room: &lt; 0.6 sec</td>
</tr>
<tr>
<td>10</td>
<td>Illuminance</td>
<td>Illuminating Engineering Society Lighting Handbook</td>
<td>300 lux</td>
</tr>
<tr>
<td>11</td>
<td>Equivalent Melanopic Lux (EML) with daylight</td>
<td>WELL v1</td>
<td>200 EML</td>
</tr>
<tr>
<td>12</td>
<td>EML without daylight</td>
<td>WELL v1</td>
<td>150 EML</td>
</tr>
<tr>
<td>13</td>
<td>Thermal Comfort</td>
<td>American Society of Heating, Refrigerating and Air-Conditioning Engineers 55: 2017</td>
<td>Predicted Mean Vote: -0.5 to +0.5</td>
</tr>
<tr>
<td>Serial. No.</td>
<td>Health Impacts</td>
<td>Source</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Cardiovascular and respiratory diseases, decreased lung function, irritation</td>
<td>Vehicle emissions, construction work, unattended debris, fossil fuel-based power generation, interior sources such as cooking and industrial processes.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>of the eyes, nose and throat, coughing, sneezing and shortness of breath.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Respiratory illness, irritation of the skin, eyes, nose, and throat. High</td>
<td>Adhesives, glue, combustion process, disinfectants, internal combustion engines, particle board and other pressed wood products, tobacco, treated textiles, urea formaldehyde foams, wallpaper, and finishing products.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>levels of exposure may cause some types of cancers.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Eye, nose and throat irritation, headaches, loss of coordination and nausea,</td>
<td>Finishing products, wood, preservatives, aerosol sprays, cleansers and disinfectants, moth repellents and air fresheners, stored fuels and automotive products, hobby supplies, building materials and furnishings, office equipment, stationery supplies, and photographic solutions.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>damage to liver, kidney, and central nervous system.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Irritation of the airways, aggravation of respiratory diseases, reduced lung</td>
<td>Vehicle exhaust gases, open fires, gas appliances, tobacco smoke.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>function. Long term exposure to high concentrations can cause asthma and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>increase likelihood of developing respiratory infections.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Headache, fatigue, dizziness and drowsiness. It can cause chest pain in</td>
<td>Open fires, tobacco smoke, vehicle exhaust gases.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>people with heart disease. Prolonged or high exposure can cause vomiting,</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>confusion and loss of consciousness.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Headaches, tiredness and sleepiness.</td>
<td>Building occupants are an indoor source.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Exterior noise from local traffic, air traffic, construction sites, etc.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Poor acoustics can cause lack of concentration, distraction from work and</td>
<td>Interior generated background noise from air conditioning units, people talking, floor/ceiling fan, mobile phones, refrigerator hum.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>lack of sleep.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Lack of sound absorbing surfaces in a space causes higher reverberation time.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Eye strain, dry eyes, blurry vision, headaches, decreased productivity, and a</td>
<td>Source investigated for the study: artificial light.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>negative impact on mood and emotional well-being.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Sleep deprivation or disorder, increased risk of diseases like diabetes,</td>
<td>Source investigated for the study: artificial light + daylight.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>obesity, anxiety, and hypertension.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Decreased productivity, discomfort.</td>
<td>Source investigated for the study: artificial light.</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>Heat gain from envelope, lighting, equipment, and occupants.</td>
<td></td>
</tr>
</tbody>
</table>
Appendix: Endnotes


4 System performance when the outdoor PM 2.5 levels are in ‘Poor’ or ‘Very poor’ category, could not be evaluated as there was no measurement data available for these scenarios.


7 Arc is a platform with tools to measure and score operational performance for any space or building. To know more about Arc, visit the website: https://arcskoru.com/

Acknowledgements

We are very thankful for the support we received from various stakeholders in conducting this study.

We are especially grateful to the 30 organizations who participated in this study, shared information with us and allowed us to visit their office spaces.

Our heartfelt thanks to the study advisors who guided us throughout the journey and provided their invaluable perspectives.

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