SUSTAINABLE BUSINESS & ENTERPRISE ROUNDTABLE

REAL ESTATE LEADERSHIP COUNCIL MEMBER BRIEFING:

MANAGING INDOOR AIR QUALITY

SUSTAINABILITY ROUNDTABLE, INC.
LEADERS CREATING VALUE

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Key Takeaways

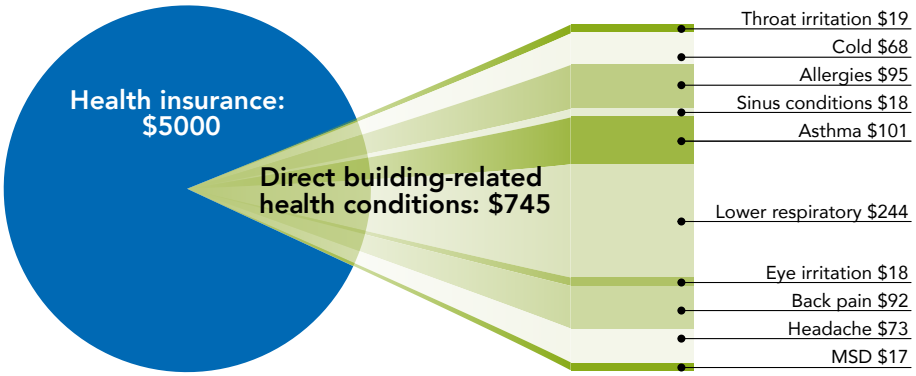
- Leading corporate users increasingly pursue IAQ management as part of their portfolio-wide sustainability strategy to reduce employee absenteeism and health care costs, improve productivity, reduce liability and regulatory risk, and improve brand and reputation.
- Leading landlords and owners are increasingly pursuing IAQ management to improve competitiveness, improve their ability to attract and retain tenants, increase property values, and reduce liability and regulatory risk.
- Leading executives have found significant payback from improvements in building design, operation, and maintenance that enhance IAQ. Such improvements often exceed the costs by a factor of ten or more because worker salaries and benefits greatly exceed the costs of providing and operating buildings.
- Executives implement source reduction as the primary strategy for improved IAQ – they establish policies for using green products in renovations and upgrades, implement green cleaning, and ban smoking inside and near buildings.
- Leaders recognize the benefits of proper ventilation to control and dilute indoor contaminants. Leaders increase ventilation above code requirements and use demand controlled ventilation, natural ventilation, mixed-mode ventilation, enhanced filtration and operational improvements to reduce both energy costs and health complaints.
- Leading companies monitor key indoor air contaminants like CO, CO_2, ozone, particulate matter, and VOCs; and go beyond the mandatory and guideline limits to improve IAQ.
- Executives are attentive to three emerging issues: (1) LEED 2012, which will include much more stringent IAQ requirements; (2) findings on semi-VOCs, which are persistent and difficult to measure and have potentially significant health effects; and (3) expanded insight into indoor air chemistry which reveals that reaction products – which are more irritating than the originating chemicals – result from the reaction of oxidizable hydrocarbons and ozone.

Introduction

Indoor Environmental Quality (IEQ) includes the complete indoor environment – airborne pollutants (addressed in IAQ) as well as noise, light, temperature, moisture and humidity, ergonomics, etc. Poor IEQ is estimated to cost the U.S. economy tens of billions of dollars a year due to increasing illness, allergic symptoms, and lost productivity. A recent study estimated that annual direct costs linked to building-related illness and health conditions are $745 per employee (see Figure 1).

Figure 1. Annual direct costs of building-related illness & health conditions.

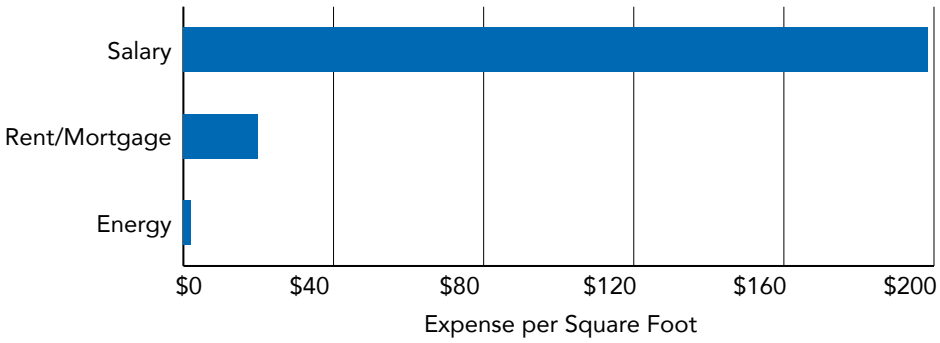
Source: Vivan Loftness, USGBC Federal Summit, 2010.



Changes in building design, operation, and maintenance that improve occupant performance can yield significant returns because the salaries and benefits of building occupants greatly exceed the costs of providing and operating buildings. As Figure 2 illustrates, salaries and benefits can be 100 to 200 times higher than energy costs alone. Recent cost-benefit analyses indicate that the **benefits from improved IEQ often exceed the costs by a factor of 10 or more**. Leading companies are recognizing the importance of a healthy work environment for improving workforce productivity. These companies are taking steps to improve the indoor air quality (IAQ) and overall environmental quality of their buildings as part of a portfolio-wide sustainability strategy.

Figure 2. Building operational costs.

Source: Vivan Loftness, USGBC Federal Summit, 2010.



Real estate executives prioritize Indoor Air Quality (IAQ), a subset of IEQ. IAQ refers to the airborne indoor environment including pollutants such as VOCs, carbon monoxide, carbon dioxide, mold and fungi, viruses and bacteria. IAQ can affect occupant comfort, health, and work performance. A growing body of scientific evidence over the past decade has demonstrated that the air within offices and other buildings can be more polluted than the outdoor air. Common office complaints include dry or burning mucous membranes in the nose, eyes, and throat, sneezing, stuffy or runny nose, fatigue or lethargy, headache, dizziness, nausea, irritability and forgetfulness. Poor indoor air quality can also lead to more serious conditions such as Legionnaires' disease, asthma, hypersensitivity pneumonitis, and humidifier fever, referred to as "building related illnesses". Table 2 provides a list of several air contaminants and aligns them with the health effects they are known to cause.

IEQ

Indoor Environmental Quality (IEQ) includes the complete indoor environment – airborne pollutants (addressed in IAQ) as well as noise, light, temperature, moisture and humidity, ergonomics, etc. For example, recent studies have linked shift work and the exposure to artificial light in office buildings to disruptions of the circadian rhythm associated with sleepiness as well as increased risk of mood disorders and cancer.

IAQ

Indoor Air Quality (IAQ) refers to the airborne indoor environment. According to the EPA, commonly found office pollutants include "environmental tobacco smoke; asbestos from insulating and fire-retardant building supplies; formaldehyde from pressed wood products; other organics from building materials, carpet, and other office furnishings; cleaning materials and activities; restroom air fresheners; paints; adhesives; copying machines, and photography and print shops; biological contaminants from dirty ventilation systems or water-damaged walls, ceilings, and carpets; and pesticides from pest management practices". There are three major reasons for poor IAQ in office buildings:

- Presence of indoor air pollution sources.
- Poorly designed, maintained, or operated ventilation systems.
- Building uses that were unanticipated or poorly planned when the building was designed or renovated.

Many leading practitioners and researchers are stepping forward to promote the importance of a healthy indoor environment. The National Institute of Health (NIH), an SRER Member-Client, has had a healthy building initiative since 1996. A consortium of universities, public sector agencies, and private sector organizations in North Carolina has been developing a Healthy Buildings Institute that would focus "on health in the design, renovation, construction, operation and maintenance of built environments". A group of subject matter experts is working with the U.S. General Services Administration (GSA) to close the gap that is present in current building rating systems in the area of IEQ. The interdisciplinary Health in Buildings Roundtable (HiBR) was recently established, "to seek innovative solutions to promote human health in the built environment, based on scientific research".[1] Chaired by NIH, the HiBR plans, "to establish metrics to measure the impact of the built environment on human health; develop business models with positive ROI, based on positive health outcomes; and, develop a database on the impact of the built environment on human health and well-being".[2] The HiBR envisions a building certification system that will promote healthy indoor environments and encourage tenants and owners to make building improvements for the purpose of achieving positive health outcomes.

While many leading executives are working on improving the overall IEQ, this SRER Member Briefing focuses only on IAQ improvements and provides information on recent developments, emerging issues, mandates, voluntary requirements, best practices, and recommendations for real estate managers.

Relevance by CRE Role

Leading corporate users as well as owners are developing specific strategies and policies to improve IAQ. Although there is some overlap in motivation for corporate users and owners/investor-advisors, much of the motivation for IAQ is different (see Figure 3).

Corporate Users

For corporate users, the main benefits of improved IAQ include reducing absenteeism, reducing health care costs, increasing employee productivity, avoiding liabilities from mold, fungi and other indoor contaminants, and mitigating regulatory risk.

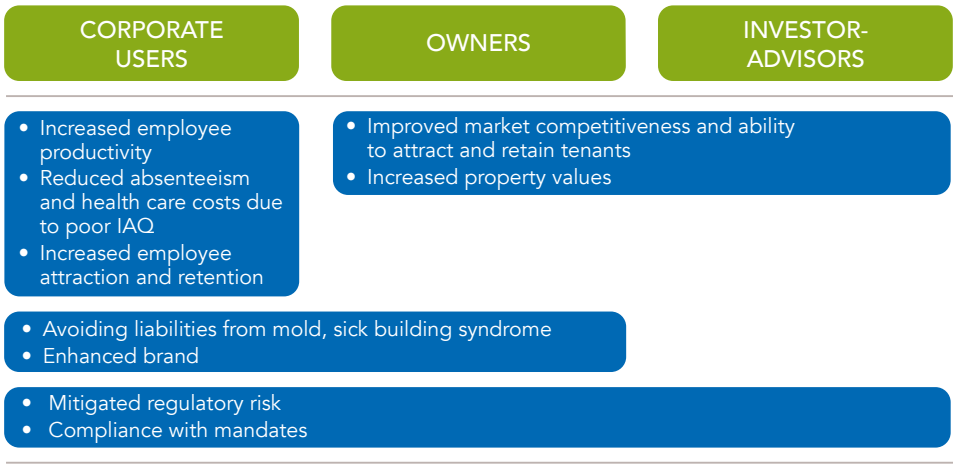
[1] Health in Buildings Roundtable.
[2] Ibid.

Owners/Investment Managers

For owners and investor advisers, the benefits include improving competitiveness and the ability to attract and retain tenants, mitigating regulatory risk, avoiding liabilities from mold and sick building syndrome, increasing property values and enhancing brand.

Figure 3. Relevance of deployment of IAQ strategy by CRE role.

Source: SR Inc analysis.



Key Drivers

Various changes over the past decade have led to greater adoption of strategies for improving IAQ in commercial buildings. A growing body of scientific knowledge has raised awareness about the increased health risks for employees which can lead to potentially significant liabilities, increased absenteeism, and reduced productivity. In addition to this, new regulations and standards to improve IAQ have prompted greater adoption of IAQ strategies by leading companies. Both of these motivations are complemented by another motivating driver which is the fact that some green building certification schemes require addressing IEQ in order to obtain certification.[3] Certification schemes that require addressing IEQ include ASHRAE 189.1, LEED (U.S.), BREEAM (UK), HQE (France), CASBEE (Japan), NABERS (Australia) and Green Star (Australia), Green Star (South Africa), Three Star (China) and the WHO (World Health Organization). The emergence of advanced green technologies and no- and low-cost green products – green cleaning products, PVC-free carpet and water-based paints – have enabled leading companies to implement IAQ source-control strategies at a low cost, thereby yielding significant ROI. Table 1 below summarizes the key market drivers for improving IAQ in commercial buildings.

[3] The new Indoor Air Quality Guide: Best Practices for Design, Construction and Commissioning is among the growing number of tools providing real estate managers with cost-effective strategies for improving IAQ.

Table 1. Market drivers for improving IAQ in commercial buildings.

Source: SR Inc research.

Key Driver	Description	Examples
Reduced Absenteeism Due to Poor IAQ	A recent study by the University of Michigan found that "improved indoor air quality contributes to reductions in perceived absenteeism and work hours affected by asthma, respiratory allergies, depression, and stress and to self-reported improvements in productivity." The authors estimated an additional 38.98 work hours per year for each occupant of a green building.[4]	A cross-sectional study in 40 buildings, covering 115 work areas and 3720 employees, found that increasing outside air ventilation rate from 12 L/s per person to 24 L/s per person reduced short-term sick leave rates by 35%.[5] Leading companies like Autodesk have measured and found improvements both in employee health outcomes and productivity from moving to a LEED-CI certified office space (for more information see SRER Report: *More Sustainable Leased Space*, 2011).
Improved Employee Productivity	In addition to improving health, better IAQ reduces fatigue, sleepiness, and thus improves concentration and productivity.	A 1997 study estimated $12 billion to $125 billion gains for U.S. from direct improvements in worker performance from better indoor environments that was not related to health (separate estimates were provided for savings from preventing different diseases).[6] Better perceived IAQ is correlated with improvements in office work tasks (approximately 1% improvement in task performance for every 10% decrease in IAQ dissatisfaction).[7]
Improved Employee Attraction and Retention	Sustainability efforts which include improved IAQ increase employee satisfaction and thus improve retention as well as help attract talent.	Interface Inc. found that 71% of full-time workers consider a company's commitment to sustainability an important criterion when evaluating a new workplace.[8] In a survey of its employees, Akamai Technologies found that 95% of employees responded favorably to its newly redesigned space which has earned LEED-CI Silver certification.[9] For more examples see SRER Report: *Integrated Alternative Workplace Strategies (AWS)*, 2011; and SRER Report: *More Sustainable Leased Space*, 2011.
Reduced Risk and Liability	Health impacts from poor IAQ such as sick building syndrome (SBS) can lead to significant liabilities for both owners and users of a building. The number of lawsuits related to IAQ is rising and the amount of damages sought is increasing. There have been recent cases resulting in settlements of $25.9 million and $35 million.[10]	In one case, the employees of a newspaper in California sued the landlord for $10 million for failing to make repairs that allowed several types of mold to grow, which they claim caused lung and sinus infection.[11]
Regulation	New codes and standards increasingly require addressing IAQ issues such as chemical exposures, CO_2 levels, and humidity. Permissible limits for many pollutants are lowered as result of emerging scientific evidence.	ASHRAE 189.1 now requires a ventilation rate for office buildings 1.3 times higher than ASHRAE 62.1 and a no smoking policy inside and within 25 feet of a building. With formaldehyde classified as a known human carcinogen (Class A) in June 2011, mandates will require its complete elimination from the indoor air environment. The U.S. Department of Health and Human Services also recently classified styrene as a chemical reasonably anticipated to be a human carcinogen.[12] The LEED 2012 draft allows for the use of mixed-mode and natural ventilation schemes and enhanced filtration designs; and promotes not only the use of low-emitting certified materials and furnishings, but also the use of environmental chamber testing according to California CDPH requirements and pre- and post-occupancy IAQ testing.
Reduced Operating Cost	Optimizing ventilation and using natural ventilation or mixed-mode ventilation can help reduce both energy costs as well as health-related costs of poor IAQ.	The Royal Bank Building in Winnipeg, Canada, achieved $33,000 annual savings and a 2.9 year simple payback from operational improvements establishing a day/night cycle for ventilation fans to reduce the oversupply of fresh air. The Philip Merrill Environmental Center hosting the Chesapeake Bay Foundation, reduced its energy costs by implementing a "socio-technical" natural ventilation (for more information, see section with best practices below).

Key Driver	Description	Examples
Increased Property Values	Buildings with good IAQ result in higher property values and are easier to rent or sell.	A 2010 study of the impact of IAQ on the value of office buildings in Singapore found that the return on investment in IAQ could be substantial (78.56%) while property values could increase by 1.28% to 3.85%.[13]
Improved Brand and Reputation	Strategies for improving IAQ as part of portfolio-wide sustainability strategy help create brand value and enhance reputation. Today intangibles like brand and reputation, innovation, risk management and human capital often represent over 80% of a company's valuation.[14]	A 2010 survey found that 67% of surveyed owners, developers and users consider the impacts on brand and reputation from green building as "important" or "very important".[15]
Advanced Green Technologies and no- and low-cost Green Products	Increasing demand and offering of green products – from carpet, to paint to cleaning supplies – has brought their cost down making them price-competitive with conventional products. For example, VOC-free products today are available at almost no additional cost.	Georgia Tech used GREENGUARD certified furniture (Teknion and Knoll) for over 80% of the School of Management building which allowed it to meet the EPA standard for IAQ in a cost-effective way. Green cleaning chemicals certified with the Design for Environment (DfE) label are also getting less expensive.
Green Building Certification	To obtain green building certification (e.g., LEED, BREEAM), real estate managers need to address IEQ in their buildings through source reduction, improved ventilation, or natural ventilation.	The first LEED Platinum building in the U.S. – the Philip Merrill Environmental Center – incorporated "socio-technical" natural ventilation system, natural flooring materials like cork and bamboo and desiccant dehumidification system to remove moisture from air and thus cut down air-conditioning.

4 S. Amanjeet, Syal M., Grady S. and S. Korkmaz, "Effects of Green Buildings on Employee Health and Productivity", American Journal of Public Health, July 15, 2010, http://news.msu.edu/media/documents/2010/08/840514e8-0b32-4aa4-9fc8-276b688dfed4.pdf.

5 Milton D.K., Glencross P.M and Walters, M.D., "Risk of sick leave associated with outdoor air supply rate, humidification and occupant complaints", Indoor Air, 10, 212-221.

6 Fisk W. and A. Rosenfeld, "Estimates of improved productivity and health from better indoor environments", Indoor Air 1997; 7; 158-172.

7 Lawrence Berkeley National Laboratory, "Impacts of indoor air environment on human performance and productivity", www.iaqscience.lbl.gov/performance-summary.html.

8 Eric Block on Sustainable Branding. 2011. New Research: 71% of American Workers Value Employers' Sustainability Commitments. http://ericblock3.wordpress.com/2011/04/07/new-research-71-of-american-workers-value-employers%E2%80%99-sustainability-commitments/.

9 Ibid.

10 AERIAS Air Quality Sciences, "Legal Issues and Guidelines", http://www.aerias.org/DesktopModules/ArticleDetail.aspx?articleId=109&spaceid=2&subid=13.

11 AERIAS Air Quality Sciences, "Legal Issues and Guidelines", http://www.aerias.org/DesktopModules/ArticleDetail.aspx?articleId=109&spaceid=2&subid=13.

12 National Institute of Health, "New Substances Added to HHS Report on Carcinogens", June 10, 2011, http://www.niehs.nih.gov/news/newsroom/releases/2011/june10/.

13 Addae-Dapaah, K. et. al., "Indoor Air Quality and Office Property Values", JOSRE, Vol. 2, No. 1, 2010, http://www.costar.com/uploadedFiles/JOSRE/JournalPdfs/05.91_116.pdf.

14 Ken Standfield, "Intangible Finance Standards: 21st Century Breakthroughs in Fundamental Analysis & Technical Analysis", Elsevier Academic Press, 2004.

15 Turner, "Green Building Market Barometer", 2010, http://www.turnerconstruction.com/Uploads/Documents/2011_Green_Building_Market_Barometer.pdf.

Occupant Health and Productivity

A vast number of studies over the past decade have demonstrated the link between indoor air quality and health. The research on IAQ was spurred in part by the growing number of illness reports from modern buildings. While increased energy efficiency has reduced the cost of heating and air-conditioning, it often results in a tight, sealed building envelope which can lead to worsening IAQ. According to the EPA Building Assessment and Survey Evaluation (BASE) study and findings from European research, 20% or more of workers experience illness symptoms at work. In a study of 41 buildings with 1,970 subjects, the EPA BASE study found that 27% of workers experienced irritation of the eye, nose and throat and 16% reported headache and fatigue.[16] According to some WHO experts, "up to 30 percent of new or remodeled commercial buildings may have unusually high rates of health and comfort complaints from occupants that may potentially be related to indoor air quality".[17]

The term "Sick Building Syndrome" (SBS) is often used to define the cluster of symptoms that are widely reported by building occupants. Still poorly understood, SBS describes situations in which building occupants experience health and comfort effects that appear to be linked to time spent in the building and which lessen after leaving the building. Commonly reported symptoms include headache, difficulty concentrating, fatigue, eye, nose and throat irritation, dry cough, dry and itchy eyes, and sensitivity to odors. Different people have different sensitivity and employees with asthma, allergies, and other health conditions are most likely to be adversely affected by poor IAQ. Figure 4 summarizes the findings of several studies looking at the correlation of increased ventilation with illness and sick days of building occupants. Table 2 lists the main contaminants found in office buildings and their potential health effects.

Figure 4. Higher ventilation rates promote health.

Sick leave (Milton study) ◆

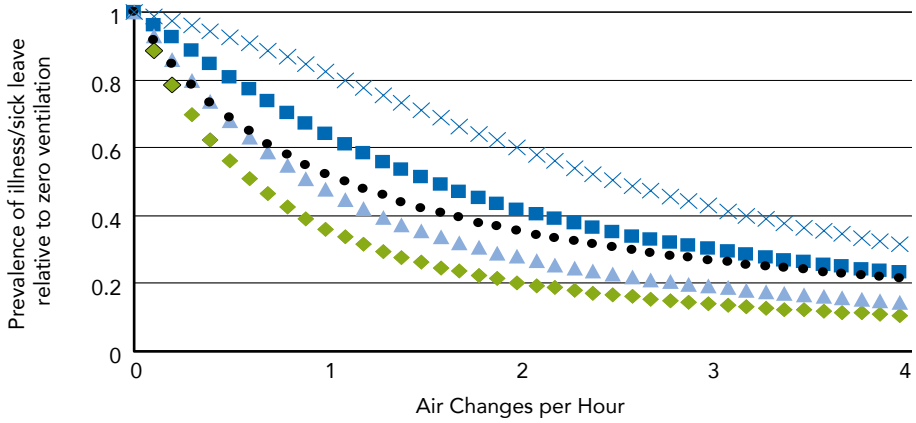
Illness (all years; Brundage study) ■

Illness (1 yr data; Brundage study) ▲

Illness (Drinka study) ×

Particle concentration model ●

Source: Fisk et al 2003, http://web1.swegon.com/upload/AirAcademy/Articles/Swegon_IAQ_and_productivity_prot.pdf.



[16] Apte et. al., 2000. From "Healthy Buildings: A proposal for a research initiative on health and indoor environments", by Judith Heerwagen, April 2010, prepared for the National Institutes of Health.

[17] Environmental Protection Agency (EPA), "A Guide to Indoor Air Quality", http://www.epa.gov/iaq/pubs/insidestory.html#Intro1.

Table 2. Main indoor contaminants, sources, and health effects.

Source: U.S. EPA, "An Introduction to Indoor Air Quality", http://www.epa.gov/iaq/ia-intro.html.

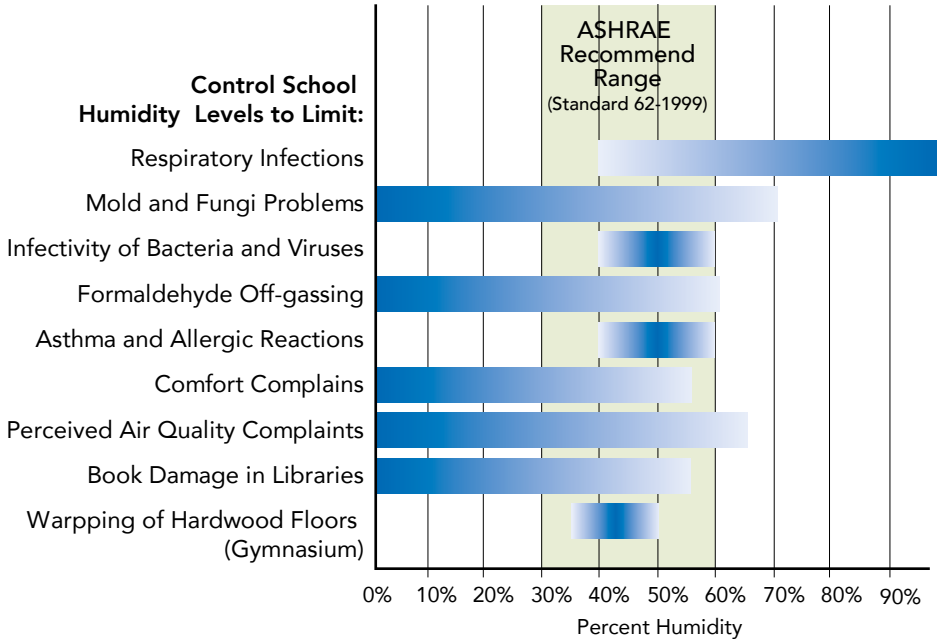
Contaminants	Source(s)	Health Effects
Carbon dioxide	Result of building occupancy and inadequate ventilation.	Fatigue, sleepiness, headaches; at higher levels it is associated with dizziness, restlessness, a tingling or pins or needles feeling, difficulty breathing, sweating, tiredness, increased heart rate, and elevated blood pressure.
Carbon monoxide	Result of incomplete combustion; can be drawn from outside (e.g., underground garages).	At low concentrations, fatigue in healthy people and chest pain in people with heart disease. At higher concentrations, impaired vision and coordination, headaches, dizziness, confusion, nausea, and sometimes death.
Environmental tobacco smoke	Smoking inside or outside a building (near airflow intake).	Eye, nose, and throat irritation; headaches; lung cancer; may contribute to heart disease.
Biological contaminants	These include bacteria, viruses, fungi including mold, dust mite allergens, animal dander and pollen. Can be drawn from outside or result of higher humidity.	Allergic reactions, including hypersensitivity pneumonitis, allergic rhinitis, and some types of asthma. Molds and mildews release disease-causing toxins. Common symptoms of health problems caused by biological pollutants include sneezing, watery eyes, coughing, shortness of breath, dizziness, lethargy, fever, and digestive problems.
Volatile Organic Compounds (VOCs)	Common VOCs include formaldehyde, toluene, acetone, ethanol, hexane, benzene. Sources of VOCs in buildings are paints, carpets, furniture, cleaning chemicals, copiers and printers.	Eye, nose, and throat irritation; headaches, loss of coordination, nausea; damage to liver, kidney, and central nervous system. Some organics can cause cancer in animals; some are suspected or known to cause cancer in humans. Formaldehyde was recently declared Class A carcinogen; styrene was recently declared as suspected carcinogen.
Semi-volatile compounds (SVOCs)	These are VOCs with higher boiling point (240-260 °C to 380-400 °C) such as pesticides, phthalates, and fire retardants, among others.	Emerging science has linked this group of chemicals (known also as endocrine disruptors or EDCs) to potentially significant health effects such as developmental, reproductive, neurological, and immune system impacts as well as cancer.
Particulate matter	Particle pollution - especially fine particles with size less than 2.5 microns - contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems.[18]	Health studies have linked exposure to particulate matter to respiratory problems, reduced lung function, aggravated asthma, development of chronic bronchitis, irregular heartbeat, and nonfatal heart attacks.
Ozone	Ozone can either be drawn from outside through the ventilation system (e.g., in non-attainment areas) or be generated by copiers and printers in office environment.	Inhaling ozone is associated with various respiratory symptoms such as throat irritation, coughing, chest tightness, wheezing, and shortness of breath. In addition, ozone exposure is associated with decreased lung function and inflammation of the airways. Ozone is also highly reactive and can combine with other indoor pollutants to form even more irritating chemicals.

[18] EPA, "Particulate matter", http://www.epa.gov/pm/health.html.

Humidity is a key parameter determining IAQ. There is no "ideal" humidity level since many factors such as personal activity and clothing may affect personal comfort. It is well established that elevated relative humidity can promote the growth of mold, bacteria, and dust mites which can aggravate allergies and asthma.[19] On the other hand, too low humidity causes dry throat and eyes, increased formaldehyde off-gassing and comfort complaints. Figure 5 identifies the humidity levels that are effective in limiting several issues compared to ASHRAE's recommended humidity range. ASHRAE recommends maintaining a relative humidity level between 30 percent and 60 percent but the recommended value for health and productivity is 45-55%.[20]

Figure 5. Humidity, IAQ and health.

Source: Charlene Bayer, Ph.D., Hygieia Sciences LLC and Georgia Institute of Technology.



Emerging Issues

Changes are continually occuring in the market and science is continually identifying new information. Emerging issues relavent to IAQ are developing and executives should remain aware of these issues. Several issues are detailed here, including LEED 2012, SVOCs and reactive products of contaminant interaction.

[19] Illinois Department of Public Health, "Guidelines for Indoor Air Quality", http://www.idph.state.il.us/envhealth/factsheets/indoorairqualityguide_fs.htm.

[20] Charlene Bayer, Ph.D., Hygieia Sciences LLC and The Georgia Institute of Technology, Sept. 16, 2011.

LEED 2012

LEED 2012 is expected to increase the mandatory and prescriptive requirements for IAQ and IEQ credits. It is expected to require pre- and post-occupancy IAQ sampling and specify maximum levels of target IAQ contaminants. In addition, the draft rating system includes emission testing of materials and furnishings (e.g., environmental chamber testing according to California CDPH requirements) as well as the use of certified materials and furnishings. LEED 2012 is expected to allow, when appropriate, for the use of mixed-mode and natural ventilation schemes and enhanced filtration (particulate and gas-phase).

Semi-Volitile Organic Coumpounds

Another emerging issue of concern is semi-volatile compounds (SVOCs) such as phthalates and flame retardants, which are still difficult to measure. They are usually persistent and yield potentially significant health effects such as endocrine disruption and bioaccumulation. Table 3 identifies SVOCs and shows how they relate to VOCs and VVOCs.

Table 3. Semi-volitile organic compounds (SVOCs).

Source: Charlene W. Bayer, Ph.D.; Hygia and Georgia Institute of Technology.

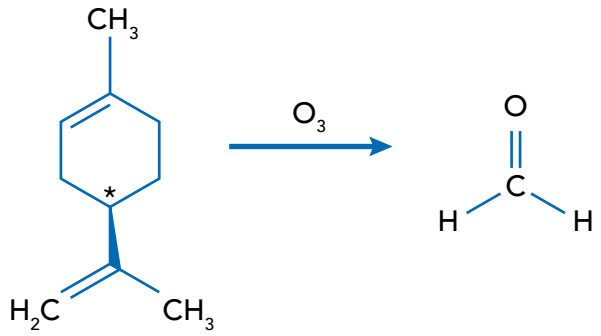
Description	Abbreviation	Boiling Point Range (°C)	Example Compounds
Very Volatile Compounds	VVOCs	<0 to 50-100	Propane & butane
Volatile Compounds	VOCs	50-100 to 240-260	Formaldehyde, toluene, acetone, ethanol, hexanal, benzene
Semi-volatile Compounds	SVOCs	240-260 to 380-400	Pesticides, phthalates (plasticizers), & fire retardants

Contaminant Interaction

While most indoor pollutants are well studied, the health effects of their combined presence are poorly understood. Moreover, there is a growing problem of **reactive products that result from the reaction of oxidizable hydrocarbons and ozone.** These reactive products are in ultrafine particulate and gaseous phases and are more irritating than the original contaminants (see Figure 6). Ozone is always present in the ambient air, but it can increase to unhealthy levels and can react to produce toxic products when combined with accumulated air contaminants and adverse weather conditions or concentrations of printing and copying equipment inside.

Figure 6. Reactive product example: oxidizable compound together with ozone produces formaldehyde.

Source: Charlene W. Bayer, Ph.D.; Hygieia LLC and Georgia Institute of Technology.



Mandatory and Voluntary Requirements

Various agencies and organizations provide guidance on recommended maximum concentrations for indoor contaminants such as carbon dioxide, carbon monoxide, ozone, lead, and particulates as well as formaldehyde and VOCs. Table 4 contains a list of the ten main organizations working in this topic. Each organization has different permissible concentrations and limits for ensuring occupant health.[21]

The U.S. EPA sets the National Ambient Air Quality Standards (NAAQS) under the Clean Air Act of 1990. These enforceable standards are applicable both for outdoor and indoor air quality. In addition, the EPA has numerous resources and guidelines on IAQ for commercial buildings.[22]

Green building certification standards such as LEED and BREEAM include requirements for improving the indoor environmental quality. Under LEED, there are credits for increased ventilation, use of low emitting materials (paints, carpet, flooring, adhesives and furniture), environmental tobacco smoke control, and other solutions. The draft of LEED 2012 significantly increases the mandatory and performance requirements for IAQ and IEQ credits. Among the proposed enhanced credits are pre- and post-occupancy IAQ sampling with required maximum levels of multiple IAQ contaminants, performance of emission testing on materials and furnishings in addition to using certified materials and furnishings and ergonomic credits. One of the ten BREEAM credit categories is "health and well-being" and buildings can earn between four and six credits for improvements in IAQ by reducing VOCs, minimizing the ingress of external pollutants, and leveraging the use of natural ventilation.[23]

[21] For more information see Table 6 in the NRCC report available at http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/rr/rr204/rr204.pdf.

[22] http://www.epa.gov/iaq/

[23] BRE Global, "Open Letter", Feb. 2011, http://www.breeam.org/filelibrary/BREEAM%202011/BREEAM_2011_Open_letter_and_summary_paper_PDF.pdf.

Table 4. Standards and guideline organizations for IAQ .

Source: National Research Council Canada, Indoor Air Quality Guidelines and Standards, http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/rr/rr204/rr204.pdf.

Acronym	Organization
ACGIH	American Conference of Governmental Industrial Hygienists
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
	Association of Environmentally Friendly Carpets (Germany)
	Building Information Foundation (Finland)
CRI	Carpet and Rug Institute
CSA	Canadian Standard Association
DFG	Deutsche Forschungs Gemeinschaft (Germany)
DSIC	Danish Society of Indoor Climate (Denmark)
EPA	U.S. Environmental Protection Agency
GEI	GreenGuard Environmental Institute
	Green Seal
GEV	Gemeinschaft Emissionskontrollierter Verlegewerkstoffe (Germany)
	Federal Environmental Agency (Germany), Indoor Air Hygiene Commission (IRK)
HRSDC	Human Resources and Skill Development Canada
MHLW	Ministry of Health, Labour and Welfare (Japan)
	Nordic Council of Ministries
NFICL	Norwegian Forum of Indoor Climate Labeling (Norway)
NIOSH	National Institute for Occupational Safety and Health
OEHHA	Office of Environmental Health Hazard Assessment (California EPA)
OSHA	Occupational Health and Safety Administration
SCS	Scientific Certification Systems
	TerraChoice Environmental Services
	The Government of the Hong Kong Special Administrative Region (Hong Kong)
WHO	World Health Organization

ASHRAE 189.1-2009

Recently ASHRAE partnered with the USGBC and the Illuminating Engineering Society of North America (IESNA) to develop **ASHRAE 189.1-2009**, a standard and model code for high-performance, more sustainable buildings. It applies to all buildings except low-rise residential buildings. One of the standard's six areas is IEQ which includes seven mandatory and two prescriptive or performance requirements.

Some of the mandatory provisions in 189.1 related to IAQ include:

- Ventilation rates: 1.3 times higher than ASHRAE 62.1 for office buildings (see Figure 6 for the impact of ventilation on illness).
- No smoking inside buildings and within 25 feet of entrances, outdoor air intakes, and operable windows.

- Outdoor air monitoring: CO_2 monitoring in densely occupied mechanically ventilated spaces and outdoor air flow rate monitoring: in non-densely occupied mechanically ventilated spaces.
- Minimum MERV 8 filtration upstream of cooling coils (revises 62.1 standard).

The prescriptive option of ASHRAE 189.1 related to IAQ includes:

- Low emitting materials (materials testing in small scale environmental chambers; modeling to show compliance with California CA/DHS/EHLB/R-7174 standard for low emitting materials).

International Building Code

The **International Building Code** (IBC) addresses IAQ through two mechanisms: minimum ventilation or air change rate requirements, including passive ventilation (e.g., through windows or infiltration); and provisions for exhaust of known sources of contamination. The code is focused mostly on energy conservation but also addresses moisture control which is important for IAQ management. ASHRAE Standard 90.1-2007 forms a basis for energy code improvements in commercial buildings.[24]

European Union Directive & Standards

Within the European Union (EU) the main regulation addressing IAQ issues is the **Energy Performance of Buildings Directive of 2010 (2010/31/EU)**. This directive promotes the improvement of the energy performance of buildings, "taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness".[25] EU Member States are required to pass laws taking the necessary measures to incorporate the directive's requirements. The directive addresses the general indoor climate conditions in order to avoid possible negative effects such as inadequate ventilation, local conditions and the designated function and age of the building. Several EU standards have been developed based on the Energy Performance of Buildings Directive. Standard **EN 15251** specifies indoor environmental input parameters for the design and assessment of energy performance of buildings. This standard addresses indoor air quality, thermal environment, lighting and acoustics. Standard **EN 13779** applies to the design and implementation of ventilation and room conditioning in non-residential buildings intended for human occupancy and does not apply to industrial process buildings.

[24] Detailed information on the building code requirements and provisions of ASHRAE Standard 62.1-2010 can be found in Table 2b of the report "Building Codes and Indoor Air Quality" prepared by David Mudarri, The Cadmus Group, for the U.S. EPA (see http://www.epa.gov/iaq/pdfs/building_codes_and_iaq.pdf).

[25] REHVA, "Indoor and outdoor Environmental Quality", http://www.rehva.eu/en/indoor-and-outdoor-environmental-quality

Adopted in 2007, EN13779 is a major step forward for IAQ as it recognizes the importance of external air quality in achieving better indoor air quality and a healthier environment. It recommends the use of different ventilation levels and filters based on the quality of outdoor air.[26]

Voluntary Rating Systems

Several other international requirements and green building certification systems exist that incorporate requirements for IAQ, such as:

Green Globes (U.S.)

This assessment and rating system, used in Canada and the U.S., was developed based on the Building Research Establishment's Environmental Assessment Method (BREEAM). In the U.S., the Green Globes is operated by the Green Building Initiative (GBI); and in Canada by BOMA Canada.[27] The assessment includes 150 questions in seven main categories, one of which is indoor environment. Some of the Green Globes requirements for minimizing contaminants in the indoor air and ensuring occupant well-being and comfort include: implementing design measures to prevent the growth of fungus, mold and bacteria; designing a humidification system; mitigating pollution at source through isolation, ventilation and materials selection; and providing CO monitoring in enclosed parking garages. Once a building design has been assessed a third-party review may be conducted. After verification, a project is awarded a Green Globes certificate.[28]

CASBEE (Japan)

The Comprehensive Assessment System for Built Environment Efficiency (CASBEE) was developed in 2002 and is used in Japan and Asia. It assesses and rates the environmental performance of buildings in five grades: Excellent, Very Good, Good, Fairly Poor and Poor. It is the first attempt in the world to apply an eco-efficiency approach to a building and is based on three concepts: (a) consideration of lifecycle stages of buildings, (b) two environmental aspects – environmental load and quality of building performance – and (c) building environmental efficiency as an indicator based on eco-efficiency.[29] The latest revision of CASBEE in 2010 included life-cycle assessment of the building system. The CASBEE Framework

[26] AAF International, European Standard EN13779:2007. Filter Recommendation For Achieving Optimal IAQ, http://www.aafeurope.com/en/155/en13779-2007-standard.

[27] Green Globes, "What is Green Globes?", http://www.greenglobes.com/about.asp.

[28] Green Globes, "Design for New Buildings and Retrofits: Rating System and Program Summary", December 2004, http://www.greenglobes.com/design/Green_Globes_Design_Summary.pdf.

[29] Takashi Akimoto, "What can we learn from CASBEE and Green Building in Japan?", Greening the City Presentation, March 15, 2010, http://www.jetro.org/documents/green_innov/Takashi_Akimoto_Presentation.pdf

represents four assessment tools for the four main stages of a building: CASBEE for Pre-design, CASBEE for New Construction, CASBEE for Existing Buildings and CASBEE for Renovation.[30] The standard's category Quality of Building Performance includes IAQ.

NABERS (Australia)

Developed originally as an energy efficiency rating tool for office buildings, the National Australian Built Environmental Ratings Scheme (NABERS) is a federal program administered by the NSW Office of Environment and Heritage, which is used by building owners and tenants to benchmark not only the greenhouse gas emissions of their buildings, but also their water, waste and indoor environmental performance. Using 12 months of data, NABERS provides star ratings. In August 2011 NABERS extended the rating system from five to six stars to reflect the improving performance of many buildings.[31]

Green Star (Australia)

Green Star, on the other hand, is managed by the Green Building Council of Australia (GBCA) and its ratings assess the environmental potential of office buildings based on design information, not actual performance. Green Star takes into consideration a wider range of topics when determining the rating. One of the topics considered is indoor environmental quality.[32]

HQE (France)

The French standard for green building, High Quality Environment (HQE), consists of two elements: (a) an environmental management system for the organization, and (b) environmental building quality requirements for operations. IAQ issues are addressed under the second element which includes 14 targets grouped into four main categories: eco-construction, eco-management, comfort, and health. Under the category of health, real estate managers need to address the sanitary quality of spaces, air quality, and water quality. Under the comfort category buildings need to ensure hygrometric comfort, acoustic comfort, visual comfort, and no unpleasant odors.[33] Recently BRE Global, CSTB and CERTIVEA (two organizations

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[30] CASBEE, "An Overview of CASBEE", http://www.ibec.or.jp/CASBEE/english/overviewE.htm.

[31] GBCA, "NABERS' move to six stars great for green building", http://www.gbca.org.au/media-centre/gbca-media-releases/nabers-move-to-six-stars-great-for-green-buildings/33639.htm.

[32] Australian Government Department of Climate Change and Energy Efficiency, "NABERS and Green Star Ratings", http://www.climatechange.gov.au/government/initiatives/eego/green-lease-schedule/nabers-green-star.aspx.

[33] Certivea International, "For creating a sustainable future", 2009, http://www.certivea.fr/ressource/data/documentations/construction/BROC_HQEIAL.pdf.

working on building certification in France) began work on aligning HQE and BREEAM to develop a common European Union assessment method and brand.

Protocollo ITACA (Italy)

In April 2011 an updated version of the Italian standard for green building "Protocol ITACA" was published in response to the EU Directive 2010/31/CE requiring almost "zero" fossil fuel consumption for public buildings by 2020.[34] The update was also done to align the assessment tool with new technical standards on energy efficiency – UNI 11300 series and the Guidelines for national energy certification.[35] IAQ is considered among the "complementary issues" and is mandated only at a regional level. In 2009, a Draft Law on Building Quality was adopted which mandates considering "the satisfaction of the physical and psychological needs of the building user" in addition to energy efficiency and ecological impacts.

Barriers & Solutions

While awareness about the impacts of IAQ on employee health and productivity is growing, there is still poor understanding of the economic benefits and large ROI from improved indoor environments. Table 5 provides an example of a ROI calculation conducted for an IAQ upgrade project and Figure 7 provides a graphical representation of the economic impact that increased ventilation rates (at varying cubic feet per minute increases) have due to increased worker performance. It is also important to note that in their pursuit of lower energy costs through tighter building envelopes, among other strategies, designers of many green buildings have *lowered* the indoor air quality for occupants compared to conventional space.

The limited control many users have over their environments and the lack of best practices and benchmarking on IAQ in commercial buildings are additional barriers to implementing an IAQ strategy as part of a portfolio-wide sustainability strategy. Table 6 summarizes the main barriers to better IAQ and recommends strategies for overcoming them.

[34] ITACA, 2011, http://www.itaca.org (in Italian, for english translation of site use http://translate.google.com/).

[35] PRC, "The ITACA Protocol", http://ec.europa.eu/enterprise/sectors/construction/files/compet/national-building-regulations/prc-it_en.pdf.

Figure 7. Higher ventilation rates increase occupant performance.

Source: Charlene Bayer, Ph.D., Hygieia Sciences LLC and Georgia Institute of Technology.

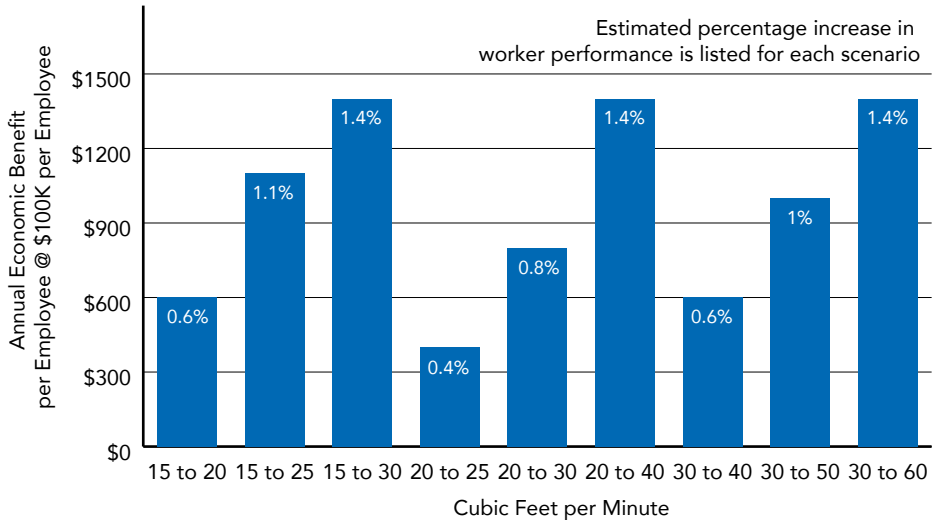


Table 5. Higher ventilation rates yield economic returns.

Source: Myatt et al 2004. Vivan Loftness, USGBC Federal Summit, 2010.

First cost increase:	$6 / employee
Annual energy cost increase:	$9 / employee
Annual health savings:	$3 / employee
Annual productivity savings:	$9 / employee
ROI:	50%

Table 6. Barriers to better indoor air quality in commercial buildings.

Source: SR Inc research.

Barrier	Strategy for Overcoming
Limited knowledge about the health impacts of IAQ, especially combined exposures	Identify existing studies, educate and train staff, support research
Few standardized methods for measuring IAQ pollutants such as phthalates and styrene exist and pollutant levels vary significantly between buildings	Hire experienced industrial hygienist to assess the building, conduct measurements and address problems.
No mandates for improving IAQ besides the ventilation rates and CO and CO_2 levels	Follow established guidelines for best practices (EPA's, for example).
Overestimated cost of intervention, and poor understanding of the economic benefits of better IAQ	Conduct life-cycle cost assessment
Lack of defined IAQ best practices	Learn from leaders and share best practices
Lack of IAQ benchmarking	Benchmark buildings, portfolio; benchmark with peers
Limited control over building environment	Landlords and tenants collaborate; set roles and responsibilities in lease contract.
High hurdle rates for projects	Estimate the NPV from improved IAQ based on lifecycle cost assessment; take advantage of incentives and rebates; educate top management.
Perceived higher operating costs (e.g. higher energy costs for increased ventilation)	Conduct life-cycle cost assessment; incorporate source reduction and innovative technologies to reduce energy use and ventilation needs.

Industry Case Studies

There is still limited information about the strategies that leading companies are implementing to improve IAQ in commercial offices. Most available information comes from public buildings and schools. Summarized below are five case studies of best practices for improving IAQ.

Steelcase Corporate Development Center

The Steelcase Corporate Development Center in Michigan was opened in 1989 and includes 500,000 square feet space. Fifty eight percent of the building is devoted to offices and public space and 42% is devoted to laboratories and building support services.

Motivation

The main purpose of the more sustainable aspects of the building was to provide a productive environment for all employees. This was intended to encourage communication and creativity for the 800 product-development professionals to help them create innovative office products, programs, and services in shorter time frames.[36]

Implementation

The building was designed to improve IAQ through source control of emissions, proper ventilation and filtration, environmental control of temperature and humidity, and proper maintenance. Source control was implemented by selecting non-toxic building materials for flooring, paints and finishes. Ventilation contamination was controlled through 35% dust-stop efficiency pre-filters and 60% efficiency final filters. The design avoided use of expensive HEPA filters by maintaining large flow rates to dilute any remaining contaminants. The ventilation rate was up to 35 liters per second (L/s) of outside air, compared to the ASHRAE requirement of 10 L/s per person. Both temperature and humidity were controlled for maximum comfort (the thermostat was set at 23 °C/77 °F). Building management implemented a comprehensive computerized scheduling program of preventive maintenance for all building systems. Every month the filters were replaced and key equipment was inspected and replaced if necessary. The heating and cooling coils were cleaned annually. To prevent dust and microorganism accumulating in the building, housekeeping included frequent carpet cleaning. For some high traffic areas, carpet was shampooed every other day.

[36] Public Works and Government Services Canada, The Environmentally Responsible Construction and Renovation Handbook, Chapter 3 – Indoor Air Quality and Materials Selection, 2000, http://www.tpsgc-pwgsc.gc.ca/biens-property/gd-env-cnstrctn/index-eng.html.

Results

The result of the IAQ strategy was significantly lower quantities of airborne contaminants than the threshold values specified by ASHRAE standard 62-89, as detailed in Table 7.

Table 7. Contaminant levels of Steelcase Center versus ASHRAE.

Source: http://www.tpsgc-pwgsc.gc.ca/biens-property/gd-env-cnstrctn/page-3-eng.html#sd8

Contaminant	Steelcase Building	ASHRAE Standard
CO	Not detectable	9 ppm
CO_2	531 ppm	1000 ppm
Respirable-suspended particulates (RSP)	19 µg/m3	50 µ g/m3
Formaldehyde	0.021 ppm	0.1 ppm

Ridgehaven Office Building

The Ridgehaven Office Building houses the City of San Diego Environmental Services Department (ESD) and was originally built in 1981. Its total area is 73,000 square feet.

Motivation

In the 1998 renovation, the ESD wanted to achieve "greater energy efficiency at a reasonable cost". Healthy indoor air quality was a primary goal and management wanted to "avoid sick building syndrome and create a healthy building environment for all of its employees".[37]

Implementation

The improved air quality of the building was achieved by a combination of careful material selection, a new mechanical system design, environmental construction methods, and a healthful building maintenance plan. The following practices were implemented:

Materials with minimal chemical emissions

The project team established environmental criteria for materials selection such as minimal chemical emissions and VOCs during installation. Building products were selected to inhibit the growth of biological contaminants. Selected low-VOC paints, sealers, and stains had to meet the South Coast Air Quality Management District (SCAQMD) requirements for low-VOC coatings and did not contain any formaldehyde, petroleum-based solvents or other toxics. Selected carpet tiles met the State of Washington Indoor Air Quality Specification criteria for low-VOC product, their backing had anti-microbial properties and their installation involved

[37] Ibid.

minimal use of low-VOC adhesives. Flooring consisted of sheets of linoleum which is a material with minimal VOCs and natural anti-microbial properties.

New mechanical system for air control

The metal ducting of the new system was insulated on the exterior with a foil-faced batt to prevent man-made mineral fibers from becoming airborne in the HVAC system. The new ventilation system met the requirements of ASHRAE 62-89 standard.

Building maintenance for occupant health and worker safety

The main priority for building maintenance was to ensure occupant health and worker safety. Most cleaning products were non-toxic, water-based, and had minimal chemical emissions. In addition, pesticide use was avoided by implementing a least-toxic pest control plan.

Results

The building had no noticeable "new building smell" or odor two weeks after occupancy, something commonly present in renovated buildings due to chemical emissions from paints, furnishing, and other new materials. Anecdotal evidence from chemically sensitive employees indicated a healthier indoor environment for this green building. The city also reported lower absenteeism and higher employee productivity.

Philip Merrill Environmental Center

The Philip Merrill Center, located in Annapolis, Maryland, houses the Chesapeake Bay Foundation, a not-for-profit conservation organization dedicated to restoring the Chesapeake Bay. The Center (see Figure 8) became the first LEED Platinum certified building in the U.S.

Motivation

The Chesapeake Bay Foundation wanted to demonstrate its sustainability commitment and provide a healthy and productive work environment for its 90 employees and thousands of visitors each year (the Center works with over 35,000 students each year).

Implementation

The strategy to improve IAQ was based on the requirements for LEED certification, and included:

- A "socio-technical" natural ventilation system utilizing environmental monitoring to control windows opening and alerting occupants when it was acceptable to open the windows.
- Open plan office space to enhance access of fresh air from all areas of the building.
- Use of renewable and natural materials such as cork and bamboo for flooring.
- Use of water-based adhesives and paints.
- Implementing desiccant dehumidification to remove moisture from air and thus reduce the need for air-conditioning, leading to cost savings from lower energy use.

Figure 8. Philip Merrill Environmental Center

Source: http://www.wbdg.org/pdfs/human_factors_cbf.pdf

Results

Four years after Chesapeake Bay Foundation staff moved into the new building, a study was conducted to evaluate the human factor impacts of sustainable design. The study, conducted by the University of California at Berkeley, included an Indoor Environmental Quality Survey, interviews and focus groups. Its main findings were as follows: [38]

- Eighty percent of building occupants experienced high levels of workplace morale.
- The building achieved the highest level of air quality satisfaction in the entire Center for the Built Environment survey database.

[38] Heerwagen, J. & Zagreus, L, "The human factors of sustainable building design: Post occupancy evaluation of the Philip Merrill Environmental Center", 2005, http://www.wbdg.org/pdfs/human_factors_cbf.pdf.

- Psychological benefits of the improved indoor environment included sense of pride – 97% of respondents said they were proud to show the office to visitors.
- One downside of the open plan design was the increased noise distraction. In a post-occupancy survey about 30% said acoustical conditions including noise and speech privacy, interfered with their work.

Royal Bank Building

Built in 1965, the Royal Bank office at 220 Portage Avenue, Winnipeg, Canada, is a 17-story building of 20,000 square meters which accommodates about 1,000 employees. The building is owned and operated by CREIT Management L.P. and its annual energy bill before the renovations was about $294,000.

Motivation

There were two main drivers behind pursuing renovations and improving the building IEQ: the desire to keep tenants happy and recognition that a 40-year old building cannot run at peak efficiency without active management. When major systems were approaching the end of their useful lives, the owner saw an opportunity to reassess what should be put into the building and possibly qualify for a greening government program. In addition, the owner wanted to create a healthier environment for occupants to reduce contaminants in the indoor air and differentiate the company in the marketplace as serving the welfare of tenants and leaving a better footprint for future generations.[39]

Implementation

An assessment of building operations revealed that ventilation fans were running 24/7 even on weekends when the building was empty. To reduce energy consumption without compromising indoor air quality, the renovations included the following:

- Operational improvements establishing a day/night cycle for ventilation fans to reduce the oversupply of fresh air but still maintain low CO_2 levels when the building was occupied.
- Installing CO_2 sensors on return air fans.
- Resetting the boiler loop temperature.

[39] Natural Resources Canada, "Case Study – Office Tower Royal Bank Building in Winnipeg", http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/eng/buildings_communities/buildings/recommissioning/publications/rcx_study_bank_winnipeg.html.

Results

As a result of the renovations the building registered a $54,000 annual savings in electricity and natural gas costs, which represented 20% of its annual energy bill.

- The cost of optimizing the ventilation system was $97,500 and resulted in over $33,000 annual savings and a simple payback period of 2.9 years.
- The installation of CO_2 sensors to regulate the return air CO_2 levels and modulate the opening of outside air dampers when CO_2 concentrations rise, cost $30,000 and resulted in natural gas savings of $16,300 (simple payback period of 1.8 years).

Estimated paybacks did not take into consideration reduced absenteeism, improved employee productivity, or increased building value.

Georgia Institute of Technology

As of 2011 Georgia Institute of Technology had over 7,000,000 square feet of more sustainable space in over 68 green buildings, five of which achieved LEED Gold certification.[40] These buildings are spread between the main Georgia Tech campus and the "Tech Square" campus. The $35 million, four-story, 330,000-square foot College of Management (see Figure 9) was the centerpiece of a $145 million, five-building project known as Technology Square.[41]

Motivation

The main motivations behind the green building program and IAQ improvements were the desire to provide a healthier environment for students and employees while demonstrating the university's commitment to sustainability. According to Bill Miller, Georgia Tech's Project Manager of Technology Square, the benefits of the indoor air quality will have "long lasting benefits to the people that occupy the space".

Implementation

The project team instituted IAQ design elements in all five buildings in the Tech Square project, including efficient ventilation and low emitting building materials and furnishings. By using GREENGUARD Certified furniture, the Management School building was able to meet the stringent EPA baseline standard for IAQ. "We could not have passed the air quality test-

[40] Georgia Tech, "Sustainability at Georgia Tech", http://www.stewardship.gatech.edu/sustainablebuildingsoverview.php.

[41] http://www.energyvortex.com/pages/headlinedetails.cfm?id=1009&archive=1

ing without low emitting furniture," admitted Dagmar Epsten, President of the Epsten Group in Atlanta, GA, who led the Georgia Tech LEED Certification. Teknion and Knoll furniture were used for the project, and both companies have certified their entire product offering to GREEGUARD. The design team at Thompson, Ventulett, Stainback (TVS) Interiors specified Teknion for 80% of the Management building's furniture.

Results

In the LEED Gold Certified Klaus Advanced Computing Center (see Figure 9) on the university campus, Georgia Tech achieved some impressive results. The Klaus Center uses 40% less energy than current energy codes through the use of more efficient lighting and natural light. The Center has preserved 50% of the site as green space and collects stormwater for irrigation. There were some challenges and important lessons learned in the post-occupant study of the Georgia Tech classrooms. The designed ventilation system was inadequate to provide sufficient fresh air and air distribution. The system was difficult to maintain and the vehicles in parking deck beneath the building were leading to higher levels of CO entering the ventilation system. The study also revealed that CO_2 levels decreased by an average of 400 ppm when the ventilation rate was raised from about 5 cfm/person to 15 cfm/person. While ASHRAE guidelines specify a CO_2 ceiling of 1,000 ppm, studies have found that when CO_2 is over 800 ppm there is a health impact.[42]

Figure 9. Georgia Institute of Technology campus – Klaus Advanced Computing Center and GIT College of Management Auditorium.

Source: Charlene Bayer, Ph.D., Hygieia Sciences LLC and Georgia Institute of Technology.

[42] Source: Charlene W. Bayer, "Healthy IAQ in Commercial Buildings: Opportunities for Customers, Building Owners, and Managers", Webinar, Sept. 22, 2011.

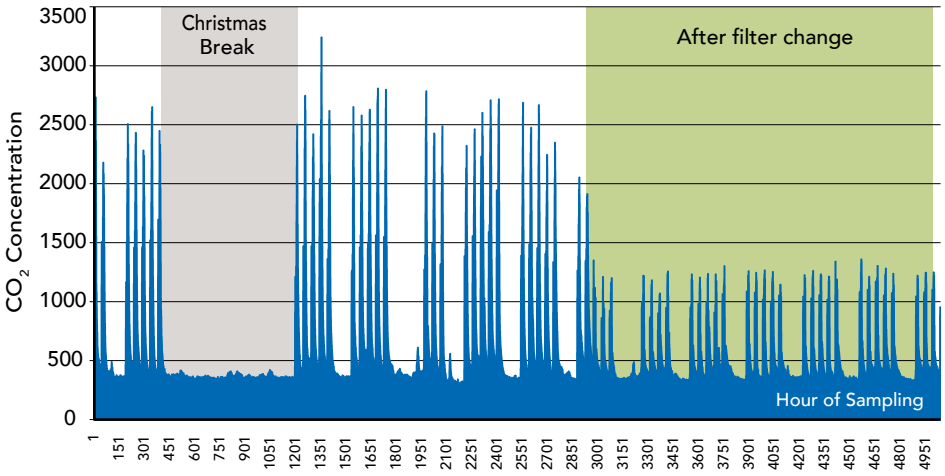
Strategy Recommendation

There are six main approaches for improving indoor air quality in a new or existing building:

- Source reduction (Table 2 provides partial list of contaminants and their sources)
- Humidity control (Figure 5 provides data to show the importance of humidity control)
- Increase fresh air ventilation rate and overall air distribution (Figure 6 shows the impact of this on health; Figure 7 models the impact of this on worker productivity and the associated economic value of that productivity.)
- Enhanced filtration systems (Figure 10 reveals the impact that filtration can have on IAQ):
  - Particle and gaseous combinations
  - Application of Indoor Air Quality Procedure; may need to maintain at least 10 L/s/person
- Improved building maintenance (Figure 10 reveals the importance of properly maintained filtration systems)
- Behavior modification & occupant education

Figure 10. Importance of filtration maintenance.

Source: Charlene Bayer, 2004. DOE-sponsored schools study.



Typically the building manager will be in charge of IAQ issues, but some companies may have an IAQ engineer or a team working on IAQ as part of a green building strategy. Other companies may prefer to hire IAQ engineer or industrial hygienist to conduct building assessment and measurements, and make recommendations for improvement.

The decision framework presented in Figure 11 provides detailed recommendations on how to incorporate these approaches in order to improve the IAQ of existing buildings.

Figure 11. Decision Framework for IAQ.
Source: SR Inc research.

Decision framework for Improving IAQ in existing commercial buildings

1. PLANNING

Collect Information on Pollutant Sources	• Using equipment information, occupancy, and existing records collect information on pollutant sources
Make the Business Case	• Gather information on costs & benefits of improved IAQ • Work with HR to gather estimates of absenteeism and productivity • Review existing complaints (if any) • Identify examples of best practices
Develop Building Profile	• Review building design and operating documents • Collect and review existing records for HVAC • Review complaint records • Conduct a walkthrough inspection of the building • Collect detailed information on HVAC system condition and operation • Collect information on pollutant sources, pathways and occupants
Identify Opportunities for IAQ Improvements	Examples of opportunities for improvement include: – Reduce CO_2 levels through increased outside air intake – No-smoking policy inside building & within 25 ft of airflow intake – Implement MERV 8 or higher filtration system – Include gas-phase filtration system when appropriate – Regularly replace air filters – Implement green cleaning – Implement integrated pest control

2. IMPLEMENTATION

Reduce IAQ Contaminants at the Source

- When renovating select materials with low or no-VOCs
- Adopt green cleaning policy and green purchasing
- Implement no-smoking policy inside building and within 25 ft of air intake
- Implement integrated pest management

Implement Humidity Control

- Maintain humidity between 45% and 55% for maximum health and productivity

Improve Ventilation

- Increase the rate of air exchange; use natural ventilation
- Implement demand-controlled ventilation
- Implement local exhaust ventilation in areas with greater pollutant loads
- Maintain at least 10 l/s/person of fresh air
- Keep CO_2 <350 ppm above outdoor levels
- Use enhanced filtration (particulate and gas-phase)

Use Enhanced Filtration Systems

- Implement particle and gaseous combinations
- Application of IAQP but may need to maintain at least 10 l/s/person

Improve Building Maintenance

- Replace air filters frequently
- Implement high performance vacuuming
- Maintain humidity within the range 45% - 55%
- Conduct inspections of key equipment; test for indoor/outdoor pollutants

Behavior Modification, Occupant Education

- Communicate IAQ strategy and practice
- Promote employee behavior modification
- Adopt procedures for proactively addressing IAQ problems

3. ASSESSMENT

Gather Data to Evaluate Results

- Regularly measure key IAQ parameters (continuously or once per year)
- Measure employee absenteeism, productivity and morale

Quantify Costs and Benefits

- Calculate the costs of IAQ improvements
- Estimate the benefits of IAQ and calculate ROI

Benchmark Internally and Externally

- Benchmark internally among different buildings
- Benchmark externally
- Document best practices

Track Emerging Issues & Requirements

- Track emerging scientific findings on impacts of IAQ on health
- Track emerging mandatory and voluntary requirements on IAQ

Communicate Internally and Externally

- Communicate internally to raise awareness and engage employees
- Communicate externally to enhance brand and reputation and attract talent

Measuring key IAQ parameters should be done at least once a year unless there are complaints or employee concerns in which case measurements should be done more often. For a list of key IAQ parameters and recommended values, see Table 8. By conducting at least yearly measurements, leading executives are developing a baseline and trend data that helps to understand complaints that might occur. In addition, leading companies measure KPIs following any renovation activities or other major building incidents (e.g., water damage). According to IAQ experts, measuring IAQ data four times a year – once every season – is ideal. However, due to the cost of such monitoring it is rarely implemented. The analytical methods for measuring many indoor air contaminants are still evolving (e.g., for phthalates and brominated flame retardants) and there is no single recommended threshold levels for optimum health and productivity.

Table 8. Common IAQ parameters and recommended values for improving employee health and productivity.

Source: SR Inc research; Dr Charlene Bayer.

IAQ Parameter	ASHRAE #	Recommended Value
Humidity	30% - 60%	45% - 55%
Temperature	68 F – 79 F	72 F – 76 F
CO_2	1000 ppm	<350 ppm above outdoor air ppm
CO	9 ppm (8 hours)	<5 ppm
O_3	0.08 ppm (8 hours)	<0.075 ppm
CH_2O	NA	27 ppb (no safe level)
PM2.5	15 ug/m3	10 ug/m3
SVOCs	NA	None determined
Styrene	NA	None determined (no safe level)
Pesticides	NA	None determined
Ventilation Rate	15 cfm/person	>35 cfm/person

Resources

- List of guidelines and standards for IAQ in North America:
  http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/rr/rr204/rr204.pdf
- Occupant Indoor Environmental Quality (IEQ) Survey and Building Benchmarking – Center for the Built Environment
  http://www.cbe.berkeley.edu/research/briefs-survey.htm
- The Indoor Air Quality Building Education and Assessment Model (I-BEAM), released in 2002 – EPA
  A guidance tool designed for use by building professionals and others interested in indoor air quality in commercial buildings.
  http://www.epa.gov/iaq/largebldgs/i-beam/index.html
- An Office Building Occupant's Guide to Indoor Air Quality – EPA
  http://www.epa.gov/iaq/pubs/occupgd.html
- Developing an IAQ Profile – EPA
  A good tool with flow chart and checklist
  http://www.epa.gov/iaq/largebldgs/pdf_files/sec_4.pdf
- Technologies to improve IAQ – Energy Center of Wisconsin
  Factsheet and comparisons
  http://www.ecw.org/ecwresults/315-1.pdf
- Building Assessment Survey and Evaluation Study (BASE) – EPA
  http://www.epa.gov/iaq/base/index.html
- Indoor Air Quality Benchmarking for Air Conditioned Offices
  http://onlinelibrary.wiley.com/doi/10.1002/clen.200800221/pdf
- Tailoring Lease Specification – SAIF Corporation, IAQ
  http://www.saif.com/_files/SafetyHealthGuides/s-852.pdf
- Occupant Satisfaction, Health & Productivity – USGBC
  A list of studies.
  http://www.usgbc.org/DisplayPage.aspx?CMSPageID=77#occupant
- U.S. Indoor Air Quality Market and Trends
  http://www.bccresearch.com/report/ENV003B.html
- Indoor Air Quality Guidelines and Standards, RR-204 – Charles K; Magee RJ; Won D; and Luszty E. 2005. National Research Council Canada
  www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/rr/rr204/rr204.pdf
- Indoor Air Quality in Commercial and Institutional Buildings – OSHA, 2011
  http://www.osha.gov/Publications/3430indoor-air-quality-sm.pdf

- Public Health and Economic Impact of Dampness and Mold, 2007, Mudarri, D. & Fisk, W.
  This study found that exposure to dampness and mold in buildings poses significant public health and economic risks. 21% of asthma cases in the U.S. are attributable to dampness and mold exposure in the home, resulting in an economic impact of $3.5 billion each year.
  http://www.iaqscience.lbl.gov/pdfs/mold-2.pdf
- The Human Factors of Sustainable Building Design: Post Occupancy Evaluation of the Philip Merrill Environmental Center 2005 – Heerwagen, J. & Zagreus, L.
  This study evaluated occupant satisfaction in the first LEED Platinum building in the United States. Building occupants demonstrate 90% satisfaction with daylighting and 80% experience high levels of workplace morale. Moreover, the building achieved the highest level of air quality satisfaction in the entire Center for the Built Environment survey database.
  http://escholarship.org/uc/item/67j1418w#page-4
- Indoor Air Quality in Office Buildings: A Technical Guide – Health Canada Guidelines
  http://www.hc-sc.gc.ca/ewh-semt/pubs/air/office_building-immeubles_bureaux/index-eng.php
- Enhance Indoor Environmental Quality – National Institute of Building Sciences
  http://www.wbdg.org/design/ieq.php
- Guidelines for Indoor Air Quality – Illinois Department of Public Health
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Member-Clients should contact SR Inc with any questions or comments. Member-Clients who have IAQ best practices they wish to share with other Member-Clients are encouraged to do so for inclusion in future updates of this report.