
PHILIPS
Smart Buildings
Illuminated, integrated, and intelligent
Reinventing workspaces: a white paper

Introduction

The traditional work environment is undergoing rapid change. Dedicated desks, like private offices with a nameplate, windows, and a door that closes, are going the way of large workstation computers and fax machines — still there, but the exception rather than the rule.

Flexibility is the new theme in offices, and it has many implications — on office design, on the management of building services, on employees' working habits and working hours, on personal control of the office environment, and on work/life balance.

Several major trends are now driving the transformation of the traditional office space. These include:

- **Globalization,** with organizations and employees frequently distributed across multiple geographical locations
- **Changing demographics,** as Gen Y, Gen Z, and Gen Next employees enter the work force, bringing with them a much more intimate and in depth engagement with social apps and online relationships
- **New social technologies,** which continue to virtualize employees' access to information, applications, services, and each other, via mobile devices and other location-independent tools
- **New management approaches** that focus on several objectives, including sustainability, the integration of IT with building services and connected devices, employee productivity and comfort, and an increasing reliance on sensor data and analytics to streamline operations
- **Economic constraints,** resulting in a surge in freelance and remote work and a growing focus on new social technologies and other forms of reliable, remote connectivity

So what will the future office look and feel like? Office designs will be much more agile and adaptable, with different kinds of spaces for collaboration, brainstorming, and solo work. Following a service model, the office of the future will adjust to changing teams, needs, topics, and tasks, rather than providing fixed, single-purpose physical spaces.

With the increasing use of personal devices and tools in professional environments, leisure and work will continue to merge. Workspaces will behave more like living spaces, with features that support employee comfort and well-being. Workers will behave more like consumers taking advantage of amenities than employees following company guidelines.

The trend toward measurement of all aspects of employee and office life will have a significant and increasing impact on how future offices function. The "quantified self" movement is becoming more mainstream, as smart phones and other wearables track employee location, motion, velocity, and interactions. Organizations are already starting to use this data for performance and process management, health tracking, recruiting, and improved personal services.

Connected lighting systems have a crucial role to play in helping businesses realize the agile, app-driven, and attractive office of the future. A connected lighting infrastructure can serve as the basis for a digital canopy, distributing sensors, location beacons, Wi-Fi access points, and other connected devices throughout illuminated office spaces. This white paper investigates several ways in which connected lighting systems can support major trends in the transformation of offices.

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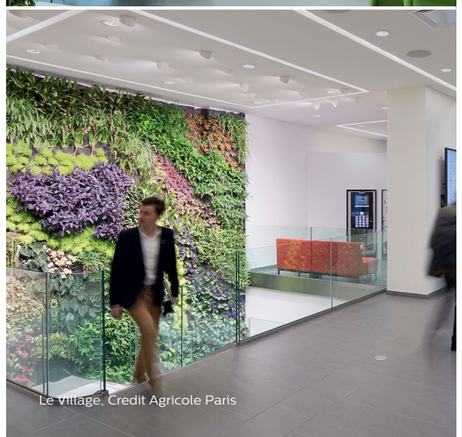


Le Village, Credit Agricole Paris

Living buildings

Although they are not taking it for granted, forward-thinking developers, owners, and tenants have started treating sustainability as a given — they simply assume that maximizing sustainability is part of their brief. In addition, they look toward a broader vision of integrating office buildings into the environment, using nature and organic design principles as inspiration.

This broader vision includes bringing nature physically into the office, via green walls, vertical gardens, indoor waterfalls and aquariums, daylighting, and work spaces that offer views of gardens and orchards. Biophilic design is catching on, especially in the US, where organizations from Google to the federal government are bringing nature into their office blueprints, strengthening the bond between humans and the natural world, even in technology-intensive spaces.

As an example, researchers have been working on building "green walls" for water cooling, eliminating the need for cooling towers. These greeen walls would also provide air filtration and new habitats for insects and birds. Innovations such as these can often save enough money to offset the costs of installation and maintenance.

While energy efficiency, cost reduction, and green building certification remain important goals, future office designs also take employee health and happiness into consideration. Flexible work spaces, app-based access to building information and services, and responsive environments can increase employee productivity, reduce employee stress, improve cognitive function, and encourage collaboration and creativity.

Eric Ubels, Chief Technology Officer at OVG, the leading real estate developer in the Netherlands, puts it this way: "Since 2004, we have only built sustainable buildings, even if the client doesn't want it. But it's not just about sustainability. It's about comfort, it's about intelligence, and more important it's about the health of people in those buildings."[1]

Sustainability: **the triple bottom line**

According to the World Business Council on Sustainable Development, "Sustainable development involves the simultaneous pursuit of economic prosperity, environmental quality and social equity. Companies aiming for sustainability need to perform not against a single, financial bottom line but against the triple bottom line."[2]

As demonstrated by innovative new office buildings, such as The Edge, in Amsterdam, LED-based connected lighting systems can provide the foundation for organizations to achieve their targets against all three of these bottom lines. Because they are distributed throughout occupied spaces, and because they can readily tie into a building's IT and management networks, LED-based connected lighting systems offer a platform for creating a "digital canopy" for delivering an entire range of advanced applications.

Sensors, integrated within the light fittings and distributed throughout the illuminated space, can give businesses rich data on occupancy patterns, energy usage, and various aspects of the indoor environment, such as light levels, carbon dioxide levels, temperature, and humidity. Building managers can use this data to adjust and fine-tune the delivery of resources to support sustainability goals. The biggest wins in this area occur when multiple services are integrated together into a single management system — for instance, when daylighting and shading systems work together with lighting and HVAC systems.

In one well-designed system, for example, shades would respond to light levels at the windows to let in the appropriate amount of daylight. An algorithm could govern the proper degree of shading, taking into account glare as well as temperature levels. Electric lights would dim and brighten appropriately to supplement the amount of available daylight, or to replace daylight after the sun sets. Similarly, cooling and heating would be coordinated with the shading system, dynamically adjusting to maintain desired temperature levels along with ideal light levels.

Coordination among these systems is partly a question of sharing real-time and historical data on conditions and occupancy. Data sharing and coordinated management — through software dashboards and mobile apps, for example — depend on a level of system integration that traditional building management and sensor networks simply cannot offer. "The importance is the combination . . . In a very advanced, healthy, intelligent building, you don't just look for *a* light system, or *an* elevator system, or *a* locker system. It all needs to integrate to get to the full experience of sustainability . . . And of course, at the end of the day, it's all for the people who are working in that building," says Ubels.

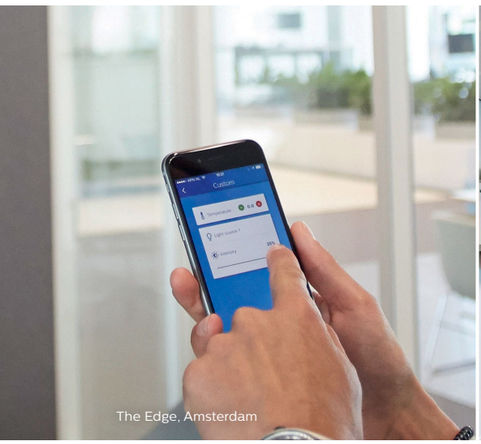
As to the latter, location beacons, also integrated into the lighting system, can create an indoor positioning grid that offers office workers new levels of personalization, convenience, and control. Businesses can use connected technology to let employees control the lighting and temperature in their immediate environment, through mobile apps that can detect employee location relative to specific luminaires and other building resources. Putting control in the hands of users allows businesses to minimize ambient light levels, reducing energy consumption while increasing employee comfort and satisfaction.

Indoor positioning, combined with occupancy sensing, and can also enable new applications that support employee comfort and efficiency, such as wayfinding; the most exciting of these new applications illustrate one definition of "smart" in the context of smart buildings. Based on knowledge of usage patterns, data on employee preferences, and real-time monitoring, the building can anticipate and automatically satisfy employee needs. For instance, the building can notify an employee of the most convenient parking space before she arrives on campus, or can reserve the best meeting room based on availability and location of invitees. The building can also recommend the most congenial place for an employee to set up for the day, based on his preference for light levels, temperature, and activity level.

Adaptive applications also have important implications for building management. Buildings that implement learning structures with the ability to adjust and adapt themselves can choose the least resource-intensive behaviors automatically, without requiring human intervention or interpretation. Organizations thus save on energy consumption while at the same time streamlining their management activities and operations. For example, the building could suggest the best available conference room for a meeting of several people who are sitting in different areas of an office floor, or on different floors. By taking into consideration the current location of each employee relative to available rooms, the building can calculate the room that will require employees to consume the least amount of electricity via elevators and interior hallways, where occupancy sensors may increase light levels as individuals pass along them.

Of course, not every building that needs a lighting or resource management system is new, so not every system can be built from scratch. New technology solutions offer sustainable lighting support in existing buildings. Lighting refurbishment and LED retrofitting programs, using wireless controls and existing electrical networks, will give many older buildings a workable and affordable path toward eventual conformity with green building targets and energy-efficiency legislation.

An increasing number of organizations are also taking advantage of innovative financing options, such as licensing or renting lighting systems, instead of owning them. These options can contribute to sustainability efforts especially when the companies licensing or renting the lighting have a vigorous recycling program in place.



The Edge, Amsterdam


The Edge, Amsterdam

The **energy-positive workplace**

Buildings contribute as much as 40% of the world's CO_2, so the impact of making buildings carbon neutral is potentially world-altering. With this in view, governments around the world are responding to the challenges of environmental change with legislation that aims to reduce emissions from all buildings to as "near to zero" as possible.

One exciting development in the smart building space is the use of different kinds of surfaces that react to the environment and manage themselves without intervention. Architect Doris Kim Sung, who teaches at the University of Southern California's School of Architecture, proposes using different material palettes to eliminate the need for massive mechanical HVAC systems, which consume an enormous amount of energy and release a lot of heat into the atmosphere.

"The human skin is the organ that naturally regulates the temperature in the body," explains Sung. "It has pores, it has sweat glands, it has all these things that work together very dynamically and very efficiently. And so what I propose is that our building skins should be more similar to human skin, and by doing so can be much more dynamic, responsive, and differentiated." [3] To this end, Sung has developed the concept of thermal bimetals, combinations of two different metals that work together to regulate heat, light levels and ventilation in buildings. These bimetals require no controls and no energy.

In 2014, materials scientists Troy Townsend and Edward Foos published a study describing a spray-on nanocrystal coating, engineered to control the amount of heat and light that can pass through it. The nanocrystals would be applied to the outsides of windows, where they are invisible to building occupants. The coating admits natural light while allowing the interior spaces to remain cool. Artificial light would be required only on especially bright days when windows need to be shaded.

Innovations in materials such as these promise to do much to help buildings achieve the coveted Net Zero Energy building certification from the International Living Future Institute. To achieve Net Zero Energy status, "One hundred percent of the project's energy needs must be supplied by on-site renewable energy on a net annual basis, without the use of on-site combustion," and the building must also meet requirements related to appropriate siting, beauty and spirit, and inspiration and education. [4]

Because the bar has been set so high, very few buildings in the world have achieved legitimate net zero status. Still, some thinkers are looking beyond the energy-neutral horizon to envision buildings that are energy positive — that is, that produce more energy than they consume. Eric Ubels is keen to point out that The Edge employs a combination of technologies — including solar panel façades, connected lighting that can automatically adapt to changing lighting conditions, and aquifer thermal energy storage — to achieve energy efficiency of 102% — that is, the building is more than neutral.

"A neutral building up til today does not exist, if you include the coffee machines, the computers, the screens, and all the technology that you put in the building," says Ubels.

"But [at The Edge,] all the energy being used for the building itself is produced by the building, even slightly more than that." [5]

Net zero by 2050

The World Green Building Council (WorldGBC) recently announced Advancing Net Zero, a project to ensure that all buildings are net zero by 2050. In this ambitious initiative, "net zero" means either "net zero energy" or "net zero carbon." Like the definition used by the International Living Futures Institute, net zero energy here means that all of the energy needed to power the building is generated through on-site renewable resources. According to Architecture 2030, a non-profit organization whose mission is to rapidly transform the built environment in response to the climate change crisis, a net zero building is a building which achieves net zero carbon emissions annually through energy efficiency and on-site or off-site renewable energy. [6] "The definition of zero carbon varies across countries (and schemes), but can include an element of carbon offsetting," adds the WorldGBC. [7]

Because the definition of "net zero" can differ in different locations, the WorldGBC plans to work with national Green Building Councils to establish certifications in the countries that they administer. Initial participating countries include Australia, Brazil, Canada, Germany, India, Netherlands, South Africa, and Sweden, each of which will develop trainings for green building professionals.

How important is the net zero project? Very. The International Energy Agency (IEA) estimates that carbon emissions from buildings, if they continue unchecked, will contribute 6°C to global warming by the end of the century. [8] What would happen then, according to leading scientists? "Such a rise," the London's *Independent* newspaper reported, in 2009, "would have cataclysmic and irreversible consequences for the Earth, making large parts of the planet uninhabitable and threatening the basis of human civilisation." [9]

The last time global temperatures rose to such an extreme, at the end of the Permian, 251 million years ago, 95% of all species on earth were wiped out. Whether or not such doomsday projections will come to pass, it's clear that drastic measures must be taken to mitigate the threat of global warming by reducing the dozens of gigatons of CO_2 that buildings are emitting. Terri Wills, CEO of WorldGBC, has said, "The success of our ambitions to keep global warming to within 1.5 to 2 degrees will depend on our ability to advance net zero buildings . . . Net zero buildings will be a defining contribution in our efforts to tackle climate change." [10]

Advancing Net Zero is also significant as it puts into action the commitment that WorldGBC made at COP 21, the most recent meeting of the United Nations Framework Convention on Climate Change (UNFCCC), which was held toward the end of 2015 in Paris, France. The key result of COP 21 was the Paris Agreement, a global agreement on the reduction of climate change, which sets a goal of limiting global warming to less than 2°C compared to pre-industrial levels. [11] In support of the Paris Agreement, WorldGBC, its 74 Green Building Councils, and their 27,000 member companies around the globe, committed to eliminating 84 gigatons of carbon emissions by 2050, through net zero buildings and carbon-zero renovations.

"Getting down to zero won't be easy," says Wills. "This will be a long and challenging road but together with the dedication and expertise of our Green Building Councils and partners, we can create a thriving market for highly efficient buildings and make net zero the new normal."

Ready, set, **retrofit**

To hit the 2050 target, the Advancing Net Zero initiative also sets a goal of making all renovations of the existing building stock net zero by 2030, along with all new building. Although the effort must be global to succeed, the WorldGBC is "starting in Europe where 35 per cent of buildings are over 50 years old, and are badly in need of energy efficiency improvements," as CEO Terri Wills has said. [12]

Reaching the 2030 goal requires a rapid acceleration in renovations of the existing built environment, starting now — and the WorldGBC is wasting no time. In March 2016, thirteen European Green Building Councils kicked off BUILD UPON, the world's largest collaborative project on building renovation. BUILD UPON seeks to design long-term national renovation strategies in each of the thirteen participating countries. By working with hundreds of different organizations involved in building renovations, BUILD UPON aims to establish specific actions that "will spark the retrofit revolution we need to reach 2 degrees." [13]

In practice, the pace of building renovation must double to at least 3% per year to reach the 2030 target. Focusing on building ownership and tenancy changes may prove to be an effective strategy, as the number of buildings that change owners or tenants is almost exactly the number needed to double renovation rates. To ensure that these renovations are net zero, governments and businesses must offer a combination of incentives, such as financing and other economic stimuli, and regulations and policies that enforce net zero measures. A successful strategy would likely include measures tailored specifically for public sector buildings, commercial buildings, and residential buildings.

Private and public sector commitments are also key to accelerating building renovation rates. Philips Lighting is doing its part; in December 2015, the company announced its intention to become carbon-neutral by 2020. Philips Lighting CEO Eric Rondolat also urged other leaders and businesses to set more aggressive targets to prevent climate change. "As it stands, we've reached the climate change checkout and all the contributions from around the world have proved insufficient to prevent a potentially catastrophic rise in global temperatures," Rondolat stated. "The world must set more ambitious goals to improve energy efficiency." [14]

Rondolat went on to say that "Faster adoption of LED lighting, and a drive to renovate existing city infrastructure and greater use of solar-powered LED lighting would have a huge impact." [15] LED lighting, especially when combined with digital controls and smart lighting management, is an important example of an energy-efficiency technology available today that can help achieve the crucial 2°C threshold. LED retrofits already underway offer compelling evidence. For example, a 2013 LED street lighting replacement project has helped the City

of Los Angeles, California, USA, realize a 63% reduction in energy usage, and at least US$9.5 million annual savings in operational and maintenance costs.[16]

Philips Lighting also believes that new business models, such as lighting-as-a-service, where the supplier retains ownership of the lighting system and the customer pays for the light used, can help remove investment and budget barriers that often stall renovation efforts. Philips Lighting is already achieving promising results by moving from an "invoicing hardware" approach to a "leasing services" approach. A major LED lighting renovation at Schiphol Airport in Amsterdam, the Netherlands, uses the lighting-as-a-service approach, allowing the airport to realize 50% energy savings over the legacy lighting system while virtually eliminating upfront costs.[17]

Green is good

If cutthroat Wall Street financier Gordon Gekko were a developer today, his signature line might be "Green, for lack of a better word, is good." Being green is business common sense, and ethical, social, and environmental concerns are increasingly part of corporate strategies.

This is not entirely altruism — building green can polish up an organization's brand, generate positive PR, and attract top talent, while also reducing operating costs and increasing asset value.

World Green Building Trends, a 2013 report from McGraw Hill, produced in association with the World Green Building Council, identifies a "sea change" in corporate motivation for green buildings since 2008. "At that time, 'doing the right thing' was the primary trigger for green building. The focus on market transformation in 2008 also indicates that those building green were primarily motivated by an idealistic desire to have a positive impact. However, green building is increasingly seen as a business opportunity. . . . [T]he market is being driven by the bottom line."[18]

Reports from around the industry illustrate how green thinking translates into business value. The Bank of America Tower at One Bryant Park in Manhattan was designed so that 90% of its employees had views of parks, green roofs, or rivers. According to a report by sustainability consulting and strategic planning firm Terrapin, the bank was designed "specifically to create an iconic building with the explicit purpose of attracting and retaining the best employees."[19]

According to a 2012 report from Net Impact, an international nonprofit dedicated to using the power of business to create a more socially and environmentally sustainable world, 58% of US millennials would be willing to accept less pay in order to work for an organization that shares their values, and 45% would give up 15% of their pay to have a job that seeks to make a social or environmental difference in the world.[20]

Statistics such as these show that being green is no longer a trade-off between profit and conscience. With continual technology breakthroughs and growing understanding of sustainability requirements, green thinking and good business practices are combining to create a win-win-win situation: good for employees, good for business, and good for the environment.

Back to the **future**

While the technology for creating adaptive and responsive spaces has just begun to mature in the last two years, the idea is nothing new. Innovative thinkers have been envisioning just such a transformation of working and living spaces, as far back as the late 1990s.

In 1998, Philips engaged a group of researchers at Palo Alto Ventures to develop concepts and a presentation around computing trends and responsive environments that can anticipate and seamlessly fulfill users' needs. The team included Eli Zelkha, Simon Birrell, Clark Dodsworth, and Brian Epstein, now a professor of philosophy at Tufts University in Medford, Massachusetts, USA.[21] On June 22, 1998, Roel Pieper, executive vice president for strategy and planning at Philips, delivered a keynote address, based on the group's research, at the inaugural Digital Living Room Conference in Laguna Niguel, California, USA. Although the address focused primarily on homes, it predicted significant future office trends with startling accuracy.

The address described what the researchers called "ambient intelligence" — an "implicit, anticipatory model" of human interaction with electronic devices in inhabited spaces. This model agrees in several important ways with the types of smart office spaces being constructed at The Edge and elsewhere. In the researchers' view, invisible, dedicated devices would be embedded throughout the environment. These devices would be personalized: they would know who you are, what you like, and how you tend to behave. They would adapt and change in response to you and the environment; they would, in fact, be able to *anticipate* and automatically fulfill your needs as far as possible, without conscious mediation on your part. They called this behavior "*pre*-sponsive," not just "*re*sponsive."[22]

These remarks are especially astonishing when you remember that, in 1998, all the critical components of smart spaces — the Internet of Things, connected LED-based lighting systems, sensor networks, the data storage and throughput required for mining and analyzing sensor data, ubiquitous high-speed data communications — were all at least fifteen years in the future.

"Only when there's a seamless integration of technology with life, only when technology is more than a curiosity but an everyday and unsurprising way of satisfying our everyday needs and desires — only then will we have seen the beginnings of the true technological revolution," wrote the researchers in 1998.[23] With the future office, that revolution is now here.

Keeping all this in mind, the next question is an obvious one: What further transformations can we expect over the next twenty years?

Reimagining office space

Danny Boyle's 2015 biopic, *Steve Jobs*, opens with a clip of Arthur C. Clarke, the famous science fiction writer and futurist, predicting trends in computing. Originally broadcast on Australian television in 1974, as part of the science series *Perspective*, the brief interview shows the author in a computer center, standing in front of the sort of whirring, room-sized machine that was typical in those days.

Remarkably, Clarke predicts not only the compact (personal) computer, but also the kind of connectivity we know now as the Internet, a good twenty years before it was available for general use. Clarke expands on what the world will be like when computers are both ubiquitous and essential in personal and professional life. "It will make it possible to live anywhere we like," Clarke says. "Any businessman or executive could live anywhere on earth and still do his business through a device like this. And this is a wonderful thing! It means we won't have to be stuck in cities. We can live out in the country or wherever we please, and still carry on complete interaction with other human beings, as well as other computers."[1]


The Edge, Amsterdam


Cisco, Toronto

Of trailers and shipping containers

We don't yet have research bases on the moon, and we haven't yet sent astronauts to plumb the mysteries of black holes, but the author of *2001: A Space Odyssey* quite accurately anticipated the rise of "digital nomads" — business professionals who do all of their work remotely, via the various communications channels that the Internet and cellular connectivity afford. Dutch start-up KantoorKaravaan, for example, has started offering mobile office spaces for digital nomads to work in the middle of nature. The solar-powered trailers are off-grid, but not offline: they come complete with Wi-Fi internet access, a coffee machine, and other necessities. Workers can simply bring their laptops and plug in — either individually or in groups.[2]

Part of the attraction of KantoorKaravaan and other similar workspaces is the opportunity to combine work with leisure activities, such as hiking, planting trees, or simply enjoying the natural environment. The increasing popularity of these mobile, unconventional workspaces reflects research conducted by psychologist Dr Craig Knight from the University of Exeter in the UK. His survey of over 2,000 office workers indicates that "by enriching work environments employees are happier, healthier and over 15% more productive than they are in a lean, depersonalised work environment."[3]

A related development, with examples in the UK and the Netherlands, is the rise of "plug-and-play" workspaces in nontraditional environments. How about spending the workday in a converted shipping container? ContainerVille, in the Shoreditch area of London, offers just such an experience. According to the property website, ContainerVille "is a home for start-ups and small businesses, consisting of 45 containers arranged over three floors and up-cycled into modern work spaces."[4] Each container has space for up to up to six desks, and offers 100 MB Internet, double-glazed windows, heat, electricity, and a kitchen, along with secure, 24-hour access.

The repurposing of shipping containers may be unique, but ContainerVille is just one of many pop-up, shared, and short-term flexible workspaces in London, used by loose collections of small businesses and independents. The Trampery has several locations with shared workspaces, meeting rooms, high-speed Internet, and kitchen and events facilities. TechHub has partnered with Google to support startups in eight locations across Europe and India.

These flexible, shared "co-working" spaces offer all the advantages of office life while allowing individuals and small business to work independently and without overhead costs. Professionals from participating businesses can also mingle, network, and share ideas and advice, creating new opportunities for collaboration across companies with related objectives.

According to online magazine *deskmag*, which conducts an annual Global Coworking Survey, the number of co-working locations like The Trampery, TechHub, and Central Working grew by 36% in 2015, and the number of members grew by 46%. The forecast for 2016 anticipates very positive prospects and continued growth.[5]

From employees to workforce consumers

While high-speed mobile connectivity and new workplace tools are enabling professionals to be more mobile and to collaborate remotely in ways that were not even imaginable a decade or two ago, we do not seem to be headed toward a completely decentralized workforce, with individuals scattered all over the countryside in rural "electronic cottages." On the contrary, the pace of urbanization keeps accelerating. According to statistics published by the United Nations, 54% of the world's population lives in cities today. That number is expected to increase to 66% by 2050.[6]

With more and more workers concentrated in larger and larger urban areas, the demand for innovative, collaborative, and centralized office spaces will continue to grow. Demand for workers has become so acute in technology hubs such as Silicon Valley that the housing markets often can't keep up. Companies have started building affordable housing for employees within commuting distance. Facebook, for example, has built 20,000 new housing units near its headquarters in Menlo Park, California, USA, with plans for an additional 6,500 units over the next few years. A similar phenomenon is occurring in other desirable technology-rich US locations, such as Portland, Oregon, and Seattle, Washington.[7]

Clearly, centralized office spaces are not going away any time soon. But office spaces must change to accommodate shifting demographics and worker preferences. Conventional lean office spaces with fixed desks and basic services are rapidly becoming a thing of the past. By 2040, according to a report by tech multinational Johnson Controls, workers will be "workplace consumers" who are totally in control of where, how and when they work.

To attract and retain top talent, therefore, companies are increasingly shifting away from hierarchical structures and traditional long-term working arrangements in favor of employment contracts that support flexible working times and an emerging range of radical working patterns. At the same time, real estate developers increasingly focus on offering adaptive, agile facilities that prioritize employee needs and respond to their constantly evolving demands. These facilities fluidly integrate new technologies to foster collaboration and co-creation, enhance employee comfort and productivity, keep remote workers connected to company culture, and support sustainable business practices.

Pentagon, Helsinki

Pentagon, Helsinki

Pentagon, Helsinki

Lighting **the open office**

Hot-desking and open-plan offices are becoming ever more common, as open office design concepts have begun to resonate with companies outside of the creative and technology sectors. Employers favor open-plan offices for the efficient use of space, savings on office furniture and other equipment, and the flexibility to rearrange floorplans easily as business objectives change. Employees enjoy the flexibility of being able to work anywhere, any time, but often miss having their own personal workspaces.

When creating open spaces, architects and property developers must always keep the importance of thoughtful and responsive design in mind. Intelligent systems can lower operational costs and promote maximum employee effectiveness at the same time. "In the last four to five years, we've all been focusing on sustainability and the impact technology has in an office. During this time, we've forgotten that we're designing for people. Now there's a real focus on trying to maximize human potential, performance, and productivity," says Kay Sargent, director of workplace strategies at Lend Lease.[8] Both dynamic LED lighting and connected lighting, along with the data-driven applications they support, have a central role to play here.

Human-centric lighting makes use of dynamic LED lighting, digital controls, and lighting "recipes" based on research into the effect of lighting on attention, energy, mood, and Circadian rhythms. Instead of depending exclusively on static white light, more and more offices are incorporating programmable, color-changing lighting into office designs.

Lighting recipes can use tunable white LED luminaires, which can shift the tint of white light through a range of color temperatures from warm to neutral to cool; full-color LED luminaires, which produce a complete spectrum of colors; and daylighting controls, in any combination. Cooler color temperatures, for example, can energize employees in the midafternoon hours, while warmer color temperatures can help them wind down toward the end of the workday.

Full-spectrum LED luminaires, which can produce both tunable white and full-color light, offer the ability to tint white light to create a range of subtle dynamic effects.

Dynamic lighting also supports multipurpose working spaces. Shifting the shade, intensity, and direction of white light in a conference room, for example, can optimize the room for multiple purposes, from brainstorming sessions to formal presentations to concentrated collaboration. Adding full-color light to the mix can transform a conference room into meeting space for entertaining visitors or celebrations.

Connected lighting systems, with luminaires that can collect and share data, support personalization applications in open-plan office spaces. With lightbeam communications, dynamic LED luminaires, and individual lightpoint control, for example, a worker in an open-plan office can use a smartphone app to "register" her location with the lighting system to gain control over the lighting above her desk. She can change the light levels and color temperature to her liking, and can save her preferences to instantly adjust the local lighting no matter where she sits. By tying the lighting management software to site-wide building management systems, she can even adjust the temperature and air circulation at her location.

Connected lighting systems can integrate sensor networks to create indoor positioning systems that offer a range of location-based services in offices, including wayfinding, "frictionless" access control for frequent visitors, room reservations, and requests for cleaning and other services. For example, with a specially designed smartphone app, a connected lighting system can detect when an expected visitor arrives, and automatically share the visitor's identity and the reason for his visit with the front desk or a resource scheduling application. The system would send a "badge" to the visitor's smartphone, with a scannable code to grant access to the designated area and room. If it's a large facility, the app could offer a GPS-style wayfinding map, giving the visitor step-by-step directions to the meeting room.

Online, interactive, and real-time collaboration tools get more widespread

Modern work teams do not always work in the same office but in distributed groups. Some of them may be working in co-working spaces or from home, and clients can be based all over the world. Virtual collaboration tools, software-based whiteboards, democratized teleconferencing solutions, and ubiquitous mobile devices allow office workers to combine online and face-to-face experiences in new ways.

Working the way to wellness

If you were working in an office in 2011 or 2012, you were probably startled to see one or two workplace pioneers switching from sitting to standing desks. These early adopters had taken seriously the health warnings about sitting all day, which range from chronic back pain to muscle degeneration, heart disease, osteoporosis, poor circulation, depression, and impaired brain function.[1] According to a study published in *Mayo Clinic Proceedings*, standing for at least one-quarter of the day, on the other hand, could reduce a person's risk for obesity by 32% — not an insignificant statistic if, like many office employees, you spend an average of 10 hours per workday sitting at a desk.[2]

The first standing desks were often jury-rigged affairs, with keyboards and monitors perched atop stacks of books and reams of laser printer paper. It wasn't long, though, before office furniture suppliers caught the wave, and today you can choose from a complete array of different types of standing desks, from many different manufacturers and at many different price points. Some suppliers have gone so far as to offer office walking desks — not desks that you walk around the office with, but desks outfitted with treadmills, so that you can answer your e-mails and get in a little cardio at the same time.

Despite the fact that major trend-setters, such as Google and Facebook, have adopted standing desks, there are plenty of naysayers, and much conflicting reportage on the benefits versus the hidden downsides. Recent thinking indicates that the ideal piece of equipment may be the sit-stand desk, which allows office workers to achieve the most beneficial balance between standing and sitting.

To this end, the MisterBrightLight desk, launched by a Dutch startup in 2015, aims at improving well-being by suggesting that employees use it as a standing desk after sitting for a few hours. As an additional motivation, the desk displays the calories burned while working in a standing position. It also tracks oxygen levels in the immediate vicinity and makes suggestions for improving air flow in case the levels are low.[3]

Whatever the ultimate recommendations turn out to be, the appearance of new kinds of office furniture signals a shift from the sedentary, screen-focused work style of the traditional office to a healthier work environment that incorporates physical activity and moments of mental relaxation to improve personal health and productivity.

Indeed, companies are more and more aware of the health risks and decreasing performance levels that result from sitting for ten hours or more a day. So are employees: in a 2014 survey, a staggering 87.4% of workers in the US believe that wellness positively impacts work culture, up 10% from the previous year.[4] Companies have the added incentive to promote working habits that minimize healthcare costs and health-related employee absences. Health-conscious employers are promoting a more natural, relaxing, and physically engaging working environment, using an assortment of innovations and technologies that range far beyond the standing desk. These include dynamic and connected lighting experiences that enhance comfort and productivity by supporting and respond to employees' needs.

Tuning the workspace

"Offices are sensory deprivation chambers. In the absence of sensory stimulation people get depressed. Interactivity is important, activity is important, physicality is important. Experiencing things through all of the senses is important and sorely lacking in most companies."

Steve Faktor — American futurist, digital commerce expert, and author of *Econovation: The Red, White, and Blue Pill for Arousing Innovation* — offered this damning analysis in 2013.[5] Human-centric office design is intended to counter exactly the sort of depersonalization that Faktor describes. Human-centric lighting (HCL) represents an important aspect of human-centric design in offices and other professional spaces.

Human-centric lighting is based on the discovery, in 2001, that lighting affects people's well-being through a non-visual pathway, in addition to the well-known visual pathway. The non-visual pathway makes use of a third type of photoreceptor in the human eye, in addition to the rods and cones that we require for vision. This third photoreceptor is known as photosensitive retinal ganglion cells. "With that discovery, the effects on circadian rhythms — i.e., mental, physical, and biological changes — could be correlated to specific light conditions," wrote Caroline Hayes, in the July 2015 issue of *LEDs Magazine*. While biologists and lighting experts are still working out a full understanding of photosensitive ganglion cells, the discovery "created two distinct purposes for HCL: biologically effective lighting to improve cognitive performance, and emotionally effective lighting to create stimulating environments."[6]

In practice, HCL connects in-depth knowledge of user needs, lighting applications, and the available scientific research to create evidence-based lighting experiences for optimal vision, sense of wellbeing, and performance. At a minimum, human-centric lighting applications include dynamic luminaires, controls, and a lighting recipe or timeline-based lighting scheme based on proven research into the effect of lighting on people working in office spaces.

The most capable and energy-efficient dynamic luminaires are "tunable white" LED luminaires that can produce a range of different shades of white light, from warm to neutral to cool. Different shades, or *color temperatures*, of white light have different effects on mood, atmosphere, attention, and feelings of comfort and well-being. Warm white light, like the light produced by the sun or a traditional incandescent light bulb, is often perceived as cozy and intimate, and can promote feelings of safety and relaxation. Cooler white light, like the light in a doctor's office, can seem less personal but can also energize and help support alertness. Employers can create a pleasing and motivating work environment by deploying different shades and brightnesses of light throughout the workday, based on research into the human impact of light.

The possibilities of human-centric lighting in offices are compelling, especially given the fact that employees spend as much as 36% of their waking hours at work. Lighting companies such as Philips are developing evidence-based lighting schemes that enhance worker concentration and alertness, foster cooperative behavior and creativity at dimmed lighting conditions, increase reading speed, reduce sleepiness, and increase visual and self-reported performance.

Organizations can make meaningful improvements to the well-being of office workers via light even without implementing full-fledged HCL. Simply installing tunable white luminaires and giving employees a convenient way to manage the color and intensity of the light around their workspaces can prevent eye fatigue and promote comfort and feelings of control, all of which contribute to productivity and job satisfaction.

Managing office lighting in tandem with daylighting can similarly benefit employees. Exposure to natural light at office keeps workers healthy and happy, researchers say. A study conducted by researchers at the Northwestern University Department of Neurology in Chicago, Illinois, University of Illinois at Urbana-Champaign School of Architecture, and Hwa-Hsia Institute of Technology Department of Architecture in Taipei, Taiwan, found that people working in well-lit offices reported better sleep quality, more physical activity, and improved mental well-being as compared to office-workers exposed to low levels of natural light.[7] Automated blind systems that use light sensors to open and close blinds to maximize daylight levels in offices can reduce eyestrain, which may in turn lead to improved productivity and healthier office environments.

Some innovations even connect lighting with sound. Swedish designer Johanna Jacobson Backman has designed a range of hanging acoustic panels with integrated LED lights, called Block, that aim to improve sound quality within the workplace. The slimline upholstered panels feature a strip of LED lights along the underside and an in-built cable-tidy system. The half-oval-shaped pendants are made from a soft gray textile that absorbs high- and low-frequency sounds to aid office acoustics. Block went into production with Swedish lighting brand Zero in 2015.[8]

Soundlight Comfort Ceiling, from Philips Lighting, connects lighting with sound in a different way. When people spend 90% of their time indoors, often in working environments with non-natural light, they can feel tired and stressed. Soundlight Comfort Ceiling evenly distributes light across the entire workspace, to mimic the way the sun illuminates a landscape. This "outdoor ambience indoors" helps people feel better and work more productively. The ceiling panels absorb sound, providing good acoustics for people in the illuminated space — especially welcome in open-plan offices.[9]

The Edge, Amsterdam

Beyond **task lighting**

Researchers and businesses are beginning to pay attention to workers' experience of light, beyond the amount of light needed to perform tasks, approaches to reducing glare and other forms of visual discomfort, and the use of daylighting to increase energy efficiency. Promising work is being done on how lighting affects office workers both psychologically and physiologically, including the effect of light on circadian rhythms.

Light exposure to the eyes is the most powerful regulator of the circadian cycle, the 24-hour, day-night rhythm governing sleep, mood, and alertness. Melatonin plays a large role in the process. Light stimulus tends to suppress melatonin production, which can increase depression, negatively affect mood, learning, and memory, and disrupt normal sleep-wake cycles.

According to the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute in Troy, New York, USA, "If health benefits are identified, this could have far reaching effects on sustainable lighting design as a means to achieve energy goals as well as to enhance the health and wellbeing of office workers, improve overall work effectiveness, and reduce long-term health problems associated with circadian disruption, including sleep problems, mood disorders, diabetes, obesity, cardiovascular disease and cancer."[10]

The LRC has done on-site studies of a number of office buildings to gather data on workers' specific experience, and to determine if the lighting is sufficient for circadian entrainment — that is, if the lighting is such that workers can maintain a healthy circadian rhythm, conducive to concentration, productivity, and well-being during the day, and to relaxation and rejuvenating sleep at night.

Results from a study at the Edith Green-Wendell Federal Building in Portland, Oregon, USA, were representative. Even where it appears that there is plenty of available daylight, worker behavior and even furniture placement can determine

whether the light is actually "circadian-effective." These results suggest that office and lighting designers need to pay close attention to the total lit environment, and supplement daylight with the appropriate type and level of electric light where needed.[11]

Spectrally tunable LED luminaires may be especially promising for these types of applications. Spectrally tunable LED luminaires go tunable white luminaires one better, combining multiple channels of white-light and colored LED light sources that can be digitally controlled to produce full-spectrum white light across a range of color temperatures, as well as color-changing light. With these luminaires and light recipes based on research into the best formula for circadian-effective light at each hour of the day, businesses can precisely and automatically alter the lighting the make workers' experience as effective and enjoyable as possible.

When combined with sensors that track individuals' habits, activities, and vital signs, smart systems can target lighting and other in-office experiences to support the circadian health of specific employees. Services accessible through mobile or Web-based apps could let individuals manage their own environment effectively, whether at work or at home.

Wellness is in the air

In addition to ensuring proper lighting and discovering new ways for employees to interact physically with the work environment, businesses are looking at interior climate control, from the floor to the individual level. Tracking systems can extend to the office climate — not just daylight levels and temperature, but also moisture, dust, bacteria, and noise.

Companies lose billions annually because of high absenteeism and lower productivity due to sickness and poor air quality. QwikSense, a Dutch startup, gives businesses insight into their work environment by measuring temperature, air quality, illumination, air pressure, humidity, and noise levels.

"In more than 70% of the existing utilities buildings, the air quality of the work environment is poor," write Paul Stomph, Rino Stevens, and Felix Mann, CEO, COO, and CTO of QwikSense, respectively. "Even in some new buildings with a high energy efficiency, the air quality is poor and unhealthy."[12] QwikSense offers facility management software and applications that create actionable metrics to sustain healthy and productive working conditions in offices.

The Edge, Amsterdam

Newcastle Building Society, UK

Getting **WELL**

The International WELL Building Institute (IWBI), a public benefit corporation committed to improving human health and well-being through the built environment, introduced the WELL Building Standard in 2014. The standard, which is third-party certified by Green Business Certification Inc. (GBCI), who also administers LEED certification, "is an evidence-based system for measuring, certifying and monitoring the performance of building features that impact health and well-being."[13]

The WELL Building Standard looks at the quality of air, water, nourishment, light, fitness, comfort, and mind in buildings. "WELL is grounded in a body of research that explores the connection between the buildings where we spend more than 90 percent of our time, and the health and wellness impacts on us as occupants," according to the WELL Building Standard website.[14]

The initial version of the standard targets interior commercial office spaces. Pilot standards address other interior spaces, including retail, educational, residential, and restaurants, with additional pilots planned for sports facilities, neighborhoods, healthcare, and places of public assembly.

As of January 2016, around 40 WELL projects have been completed in North America, Asia, Europe, and Australia. Altogether, about 20 million square feet of commercial office space has been registered and certified via the program.

Everybody's happy nowadays

Millennials — roughly speaking, those between the ages of 20 and 35 in 2016 — have now become the world's largest generation, with over 75 million members in the US alone.[1] As this generation assumes a majority presence in the workforce, they bring a different set of values and priorities that are changing the workplace dramatically.

"Happiness lies not in the mere possession of money, it lies in the joy of achievement, in the thrill of creative effort," said US President Franklin Delano Roosevelt, in his 1933 inaugural speech.[2] Millennials agree, as they put more emphasis on immaterial values and personal growth than they do on the ingredients of the traditional career ladder — not just money, but also other incentives, such as a great company car or a fancy office. Happiness has begun to emerge as a new corporate objective, as finding pleasure, fulfillment, and meaning at work is becoming more important to more workers.

What does happiness look like in a professional work environment, and how can organizations promote it? In practice, employees often feel happy when organizations give them more choice and freedom to create the sort of work situation that best suits them. This may mean greater choice in work styles and workspaces; greater control over working schedules; less rigid distinctions between work life and private life on the one hand, and between work and relaxation on the other; and the use of innovative technology to make workspaces more personal, flexible, and responsive.

Employees who believe that their workplaces are innovative and fun not only work harder but derive greater meaning from their jobs and maintain greater loyalty towards their organizations for longer periods of time. According to research performed in 2014 by The Energy Project in collaboration with *Harvard Business Review*, employees who feel that their work is meaningful are 2.8 times as likely to remain at their jobs.[3]

Another aspect of the shift in workplace values has to do with digitization. Digitization is something of a double-edged sword: it can make working more convenient and flexible, but it can also lead to information overload and lack of tangibility — both potential sources of stress. Workers need help sorting through the flood of data coming at them constantly, and creating amenable working conditions in a variety of circumstances. And because they spend more and more time in virtual working relationship, they need to find new ways to feel helpful and connected.

Studies indicate that workplace happiness is not only good for employ*ees*; it's also good for employ*ers*. Employee output is rarely dependent on the number of hours put in at work; instead how well the employees are treated and their work-life balance plays a more crucial role. Praise is an important element as well: the 2014 study from The Energy Project and *Harvard Business Review* states, "Those who felt recognized and appreciated by their leader reported 53% higher focus, 58% higher engagement, and a 109% higher likelihood to stay with the organization."[4]

Moving up **the bliss scale**

Science proves that fun is good for business. Based on ten years of research and dozens of real-world examples, the authors of *The Levity Effect: Why It Pays to Lighten Up*, argue against business tradition to reveal the powerful bottom-line benefits of leading with levity. "Fun at work can provide a competitive advantage, help attract and retain employees, and provide the spark to jump-start creativity," write authors Adrian Gostick and Scott Christopher. "Managers who lead with levity benefit from higher levels of employee engagement and overall success."[5]

The book shows how humor and fun in the office can help businesses communicate messages and build camaraderie for a better workplace and even bigger profits. Gostick and Christopher provide dozens of real-world examples, from leading companies such as Boeing, Nike, KPMG, and Yamaha, of injecting fun into the workday, from bongo and kazoo bands who march through the office to celebrate an employee's award, to awarding aeronautics machinists a couple of hours flying paper airplanes outside after meeting a manufacturing quota.

Companies analyzing happiness indexes for employees may go so far as to hire CHOs (Chief Happiness Officers) to attract and retain talent, especially Millennials. "Gamification" of the workplace seems ready to go mainstream, with companies using instruments such as net promoter scores to measure results. Job site CareerBliss.com performs a yearly evaluation of more than 70,000 employers in the US, and nominates companies that have made the biggest strides to improve employee happiness. UnitedHealthcare is the 2016 winner, with a "Bliss Score" of 3.67 (on a scale of 1 to 5). CareerBliss analyzes thousands of confidential employee reviews, based on ten key factors that influence employee happiness, including relationships with management, compensation and growth opportunities, and overall workplace setting and environment.[6]

While company-sponsored events like the ones that Gostick and Christopher describe can result in "a significant increase in the level of employee trust, creativity, and communication," leading to happier workers and better financials,[7] offices can also boost worker happiness by creating engaging, dynamic, and interactive physical spaces. At the Google offices in Gurgaon, India, opened in 2014, cubicles and desks in ranks are a thing of the past. Doors have been replaced by open spaces, chairs by beanbags, and meeting areas by playrooms. Employees can recharge their batteries in a napping pod, rejuvenate with a sauna or a massage, or break up the day by playing billiards, beach volleyball, video games, Foosball, ping pong, or roller hockey—all available on site.[8]

Foursquare, a local search-and-discovery service and mobile app company that made a big splash in the mobile-first technology space when it opened its doors in 2009, has done something similar in its bright and airy offices in Soho, in lower Manhattan. Each room is named and decorated to emulate a Foursquare sticker, rewards that users earn by checking in on the Foursquare app to share the places they've been and the things they've done. You can hang out in Brooklyn For Life, share your space with organic stuff in Herbivore, or get elegant in Socialite, which looks like the living room of a penthouse suite in a luxury hotel. Employees can also make use of gymnastics rings and games, and they can unwind with free food and weekly keggers.[9]

Levity means light

Happiness-inducing spaces lend themselves to playful and creative uses of light. As in storytelling architectures, color-changing LED lighting has a major role to play in shaping compelling experiences that influence mood, create meaning, and encourage creativity.

Research conducted by a group from the University of California, Berkeley, demonstrates that properly designed interactive lighting experiences increase positive affect among pedestrians. The researchers deployed "an efficient interactive lighting system focused on wellbeing, as opposed to systems focused on utility or landscaping," in downtown San Leandro, California. Passive infrared sensors detect a pedestrian's linear speed, which is then used to provide a smooth path of "on-demand" LED light that follows her as she moves along.

The research team tested and interviewed dozens of pedestrians and submitted the results to a rigorous scientific analysis. Correlations conclusively showed that interactive lighting systems can have "predictable positive emotional outcomes which, in turn, improve emotional well-being." While the research tested pedestrians in an outdoor urban environment, the researchers believe that the "expectations and needs should be equivalent to those of indoor lighting" — that is, similar interactive light experiences would also have positive emotional outcomes in interior office spaces.[10]

One stunning example of an inspiring lighting experience in an office space is Aurora, an enormous curved entryway at the DIRECTV headquarters in El Segundo, California, which opened in 2013. The installation incorporates 47,000 individually controllable, full-color LED light points in 600 specially fabricated plastic diffuser panels. The immersive, organic tunnel uses a tracking system to respond to the presence and movements of visitors with real-time lighting.[11]

The Aurora installation beautifully demonstrates the use of dynamic lighting in an office space both to promote a company's brand and to create an inspiring environment for employees and visitors. It is also an excellent example of implicit interaction design. Implicit interaction design describes an intuitive interchange between users and devices, in which devices anticipate and respond without any initiative on the users' part.[12] Interactions should be expressive and meaningful, assisting people when their attention is otherwise engaged. They should adapt their appearance and behavior to changing situations or inputs — whether those inputs are the movements of visitors through a space, as in the Aurora installation, or a data feed.[13]

The UC Berkeley research team makes some interesting recommendations for incorporating data streams from IoT devices, such as wearables and personal mobile devices, into dynamic lighting installations in indoor and outdoor spaces. "Affective design could greatly benefit from actual psychophysiological sensors that could generate immediate feedback to the lighting system. For example, a simple detection of emotion through EDA [electronic design automation], HRV [heart rate variability], limb movement, or body movement could easily help close the loop in terms of emotion management," concludes the team.[14]

Connected, LED-based lighting systems can handle just these types of real-time data streams from a variety of sources, from IoT devices to social media to custom software programs. With the ability to actively track and manage the mood and emotional mindset of employees through light, companies can use office spaces to create meaning to increase productivity, promote engagement, and enhance performance.

Visualizing inspiration

Innovation cannot survive without creativity constantly flowing. This concept is visualized through programmable LED light along the walls of the Microsoft Training Center at the Microsoft Canada Headquarters in Mississauga, Ontario, Canada. While they work, employees can watch the lights moving along the walls, a physical representation of their own thought processes.

The lighting designers installed LED lighting fixtures beneath a layer of translucent material along the blue walls of the center. They then created eight unique scenes which vary in intensity and pattern. Programs range from vertical waves of white light slowly moving across the wall to high-action effects like lightning and light ripples. The actions vary in frequency, from several bursts of light in a 10-second span to one prolonged burst every five minutes. "Speed, intensity, and pattern are calculated to express a thoughtful and professional atmosphere with a hint of curious wandering," Curtis explained.[15]

Mounted over the walls of lights are interactive touch screens that invite visitors to play games and explore Microsoft's products. Together, the lights and screens create a whimsical and dynamic exhibition designed to spark each client's creativity.

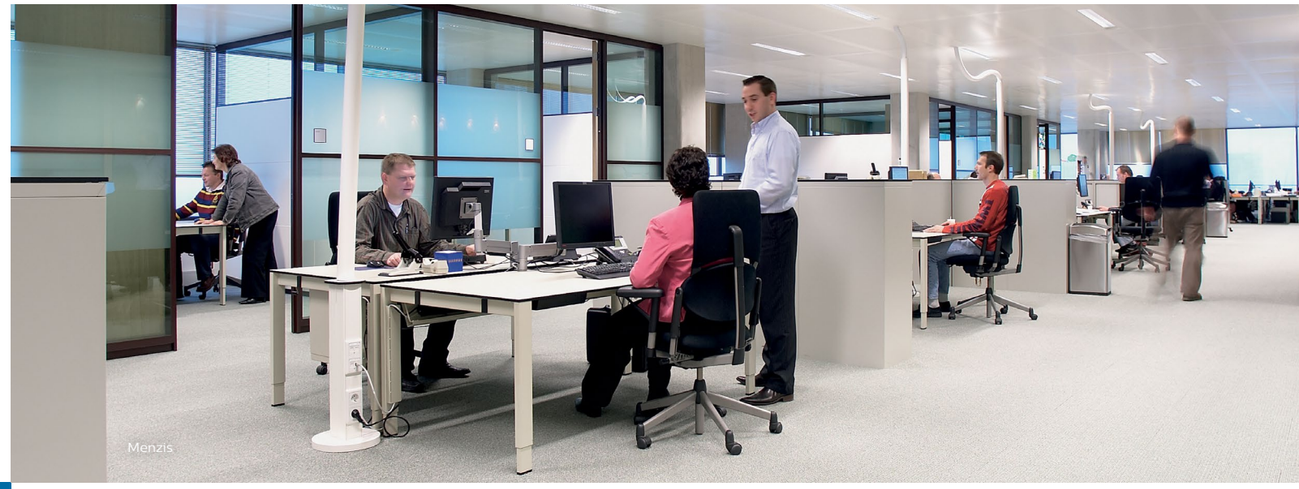
"I love how the lighting transfers a sense of depth and fluidity to the feature wall," said Curtis. "Pulses of brightness originate at the screens and travel along the length of the wall as if the data itself is being transmitted and visualized."

The new kaizen

According to the Kaizen Institute website, *kaizen* is the practice of continuous improvement.[1] When applied to the workplace, kaizen refers to the entire range of business personnel, from the C-level leaders down to rank-and-file desk employees and assembly line workers. It applies to processes, such as purchasing and logistics, as well as to people — anywhere that small, incremental changes can accumulate to fundamentally transform how business is done and how employees relate to their work environments and responsibilities.

One of the guiding principles, articulated by Masaaki Imai, who introduced the kaizen concept through his book *Kaizen*, in 1986, is "Speak with data, manage by facts." With the growing ubiquity of real-time, fixed or mobile, and often invisible sensing systems in office settings, organizations are able to acquire more data than ever before. With the ability to continuously monitor and track employee activities and usage of space, and analyze historical data using machine learning and other approaches, business gain new insights that can help them improve employee productivity, efficiency, and well-being. When combined with building management systems, this data can also help improve energy efficiency and the intelligent and cost-effective distribution of building resources.

Business are increasingly deploying sensing and monitoring capabilities in two principal ways: by creating a distributed sensor network throughout all illuminated spaces to gather real-time and historical information on activities within the walls, and by collecting data on workplace behavior from new IoT devices in the workplace, such as wearables and intelligent furnishings.



Menzis

Quantifying the workplace

As wearables such as the Apple Watch become more mainstream, companies are increasingly turning to tracking devices to gather real-time information on how individual employees and teams work and interact. Sensors embedded in employee badges or placed on office furniture can record almost any kind of staff activity.

US furniture company Steelcase, for example, has used neuroscience research to introduce new concept products for the future office. Employing various sensing devices in the work environment that gather and aggregate data, the concept system learns the preferences and needs of workers over time. Sensors and controls adjust for a wide range of variables, including temperature, noise, lighting, posture correction, and crowd control.[2]

UBIQUITOUSWEAR, an IoT package from Fujitsu currently in prototype, uses a collection of sensors, such as accelerometers, barometers, magnetometers, gyroscopes, and microphones, to communicate information about the status of people, things, and the surrounding environment. Sensors embedded in badges, tags, and sensing bands can collect data on temperature, humidity, and location. Tracking body posture and movement allows companies to immediately identify and respond to falls and other accidents. Sensing bands can track vital signs, such as pulse rate, to identify when workers are exposed to too much heat stress or other hazards.[3]

Digital health upstart Darma also offers IoT devices that can track employee health. Darma has developed a smart seat cushion that uses fiber-optic sensors that non-invasively monitor sitting behavior and vital signs. The cushion aims to help people remember to maintain an upright posture, adopt healthy sitting habits, and manage stress. As a small-scale example of the power of data storage and analysis, Darma offers actionable coaching, reminders, and advice, such as stretching guidance and breathing exercises based on individual employees' behavior and habits.[4]

In a 2015 article in *strategy+business* magazine, authors Ken Favaro and Ramesh Nair propose the term "quantified core" to describe data-driven business strategies based on

the vigorous use of embedded sensors and other tracking technologies throughout a business setting. The quantified core "is the enterprise equivalent of the 'quantified self' movement, the tracking of individuals' health and daily life patterns for the sake of improving both."[5] The authors argue that companies can reap the full benefits of the quantified core approach only by making a long-term, enterprise-wide commitment to the use of data analytics in business strategy.

One of the key attributes of a successful quantified core strategy identified by Favaro and Nair is open knowledge sharing. As Big Data becomes a fixture of office life, some workers become increasingly skeptical about wearables at the workplace. Will constant monitoring be intrusive and stressful? Will the company use analytics as a surveillance tool to keep employees in line? Is it possible to measure crucial but intangible aspects of work life such as creativity and insight? To ameliorate these concerns, and to get the most out of the data a company collects, Favaro and Nair recommend a right-to-know approach, instead of a need-to-know approach.

As the authors write, "This means adopting an explicit knowledge-sharing model that gives all internal teams the license and means to query, extract, and massage the company's data at any time, so long as privacy and confidentiality safeguards are in place."

Life **under the digital canopy**

Sensor networks are garnering a lot of attention in the technosphere these days, and for good reason. Miniaturization, high throughput, and cheap data storage now make it both possible and cost-effective to install sensors throughout public and professional spaces. Sensors can collect data about human activity — the flow of foot traffic, usage patterns, preferences; the environment — daylight levels, temperature, humidity, the presence of chemicals or other dangers; and things — the locations of items in a warehouse, traffic patterns.

Connected lighting systems have an important role to play as platforms for sensor networks, not the least in office environments. In a connected lighting system, luminaires and other lighting system devices merge with IT networks to allow for the collection, distribution, and storage of large amounts of data on systems operations, the state of the indoor environment, and activities of people in illuminated spaces. Connected luminaires use bidirectional data communications, like computers on a network, to both receive lighting command data and to send data "upstream" to database and software programs running in the company's IT environment. As with data collected from individuals via wearables and sensors embedded in office furniture, organizations can analyze, mine, and aggregate the data collected from a connected lighting system to gain new actionable insights and to automatically anticipate and fulfill the needs of workers.

Lighting offers a natural platform for intelligent, distributed systems. Lighting is already installed everywhere that employees go within a building, and power is already available everywhere that lighting is installed. By integrating sensors into the lighting system, you have a ready made, distributed grid — no need for a separate physical infrastructure, separate power runs, or separate data cabling.

Important considerations for sensor networks include the density of the grid (number of sensor nodes per area), the type of sensors deployed, and the ability to extract meaningful data from the overall data stream. Sensors have become small and cheap enough to embed directly in the luminaire housing for very little incremental cost. The density of luminaires may exceed the required density of sensors, so flexibility in commissioning is also an important consideration.

Connected luminaires are designed to make information about themselves available in standard or published data formats. Such information might include dimming level, energy consumption, time on and off, and internal temperature measurements, which can have an important effect on the performance and longevity of LED light sources.

With a database module, back-end lighting management software can store this information for historical analysis and reporting. Such information can serve as a critical part of enterprise-wide energy monitoring and management, especially as lighting often accounts for a significant percentage of an organization's energy budget. When combined with other sets of data — for example, historical information on usage of and activities in an illuminated space — system managers can use this information to refine dimming schedules and light level targets, minimizing light levels when spaces are unoccupied. The more that managers know about how and when illuminated spaces are being used, the more energy efficient their lighting operations can become.

The ability to share operational data and connectivity with IT networks is built into a connected luminaire's electronics, so it comes at little or no additional cost. Lighting manufacturers that design a common luminaire electronics platform with connected capabilities, and who use this platform across their entire portfolio of luminaires, achieve economies of scale that can actually drive the cost of connected luminaires down.

Another advantage of a common platform for connected luminaires is that businesses can use a phased approach to deploying connected capabilities. For example, an organization can take advantage of the full range of illumination capabilities in the first year of a multiyear lighting plan, then "turn on" connected capabilities by deploying lighting management software in a subsequent year.

Similarly, manufacturers of connected luminaires can incrementally expand the data that the luminaires can share with firmware updates that are easily downloaded to installed systems. In this way, the intelligence of the lighting system can grow to keep pace with an organization's evolving objectives.

Just as connected lighting systems can serve as a platform for distributed sensor networks, they can also serve as a platform for distributed communications networks, especially indoors. By outfitting connected luminaires with wireless communications, organizations can leverage the ubiquity of mobile devices to deliver in-context information and services to employees in illuminated spaces—wherever they are and whenever they need them.

With a sufficiently dense network of communications nodes, organizations can create an indoor positioning network that performs like an "indoor GPS," offering services that can contribute significantly to employee convenience and efficiency. Such services include wayfinding, directions to the nearest available parking space, advice on where in the building to sit for the day based on individual preferences and past behavior, intelligent conference room booking, and app-based control of the lighting, heating/cooling, and other aspects of an employees' immediate environment.

Toward **interconnected and renewable systems**

Businesses can use monitoring and predictive tools to support facility management, in addition to creating more responsive and productive environments for employees. Connected lighting systems, for example, can integrate with other systems in a building or city, creating new synergies and efficiencies, and making lighting an integral part of a digital ecosystem — a system of systems, in the IoT world. Given that lighting accounts for a significant percentage of energy usage worldwide, the ability to manage lighting resources along with other critical resources promises to ensure the effectiveness of green initiatives and sustainability programs.

Data aggregation and data mining, of course, exist well beyond the capabilities and concerns of lighting systems. So long as the data gathered from system operations, sensor networks, and individuals is structured in a standard or known format, it should be fairly straightforward to merge this data with data from other systems and sources.

Published interfaces allow integration of lighting management software with other management software systems, such as energy management, building management, and traffic management. Organizations that want to realize the true, game-changing value of the Internet of Things must partner with global technology experts, leaders in connected devices, and leasing software vendors and systems integrators.

The automation of the professional landscape will continue with the push toward making smart buildings the basis of a new energy system. "Smart, energy-efficient buildings can play a key role in balancing the electricity grid through proactive energy demand management and can help promote a shift away from centralised, fossil-fuel-based systems towards a decentralised, renewable, interconnected and variable system," says Volvo Construction Equipment, host of the Construction Climate Challenge, an initiative to promote sustainability in the construction industry.[6]

Cisco, Toronto

Cisco, Toronto

On the **IoT journey with Cisco**

At Light + Building, in March 2016, Akshay Thakur, Business Development Manager in the IoT/IoE Vertical and Solutions Group at Cisco, spoke about what he calls the "digital ceiling framework."[7]

According to Thakur, businesses must embrace digitization to achieve operational efficiencies via automation, deliver personalized employee experiences, and lead to innovation and new ways of working. Digitization, in Thakur's view, combines things, data, processes, and people, which work together on a network to create new experiences.

Thakur sees digital lighting as the first step to creating a "digital ceiling" — a secure infrastructure of intelligent illumination, sensing, and communication devices installed overhead and integrated into a common data network that manages all building services. For Thakur, this converged network is a key element of the building, not unlike the body's central nervous system.

To realize the promise of the digital ceiling, convergence must use an open and standards-based approach, so that the data available from all connected devices can be combined and consumed by smart building application developers to create new value and experiences for employees and employers.

According to Thakur, LED and connected lighting systems are essential to businesses achieving their sustainability goals: commercial buildings account for 23% of all global electricity use, and lighting alone accounts for 40% of overall building operational expense. Meanwhile, LED prices are dropping about 12% per year, while LED efficacy (the amount of light output per unit of energy consumed) is increasing at about 20% per year.

Thakur points to the need for a digital ecosystem to deliver effective solutions. Among other players, this ecosystem must include connected lighting suppliers, building automation partners, technology enablers (cabling and microprocessing vendors, for example), and independent software vendors who can analyze and visualize system data through dashboards and apps for the users and operators of illuminated spaces.

Thakur see the IoT journey as an evolution, not a revolution. That evolution begins with the IP convergence of building infrastructure — connecting everything to a common network. Once the converged network is in place, the system can start to provide insights and deliver smart services with analytics. The endpoint of the journey is the digital workplace, in which technology seamlessly adapts to employees' presence, and operational savings are realized by the building guiding its users, not the other way around.

Thereby hangs a tale

Branding articulates the identity, values, aspirations, beliefs, and culture of an organization. In the past few years, corporations have started to take a more comprehensive approach to brand expression. For customers, branding is about the entire experience — the name, the logo, the design aesthetic, the people, the purchasing process, the service, and the presence, both online and in the real world. Where physical workspaces were once in the background, merely facilitating, they have now become an important aspect of a company's brand, and a very visible expression of a company's culture.

According to HOK, the largest global design, architecture, engineering, and urban planning firm in the US, "The evolution of the workplace continues and is approaching the equivalent of branded stage sets designed for the theater of commerce." Creating spaces that both customers and employees can "believe into" calls for "an extension of architecture into storytelling and experience design, with the facility acting as the graphical user interface."[1]

Storytelling architecture scripts the physical experience of three-dimensional space, whether that space is an interior office space, a landmark architectural building, or a city using identity profiling to position itself as an attractive place to work and live.

Lighting plays a key role in all of three of these areas. Lighting is, in fact, an expressive and communicative element that architects and planners are more frequently "designing in" as an integral aspect of the built environment. While innovative, dynamic lighting schemes can express brand values, set the mood in an interior office space, and support comfort and collaboration, connected lighting systems and the data-driven applications that they support can open up exciting new possibilities for people to interact with the enterprise.

Digital lighting supports the ability for enterprises to display rich, brand-relevant, up-to-the-minute content, either within an office or on a building's exterior. Connected lighting creates the opportunity for customers and employees to contribute and engage via social media and other channels. "Placemaking will include spaces designed for commenting, posting, liking, sharing, and forwarding," writes HOK. "The dimensional space must join in the dialogue. It will need to interact, react, tally and exchange with those experiencing the architecture."[2]

Where **the magic happens**

Storytelling architectures that express brand values in interior office spaces are geared to employees as much as to visitors. Engaged and proud employees who live the brand are essential for business success. Equally important is a company's ability to attract a younger generation of workers with creative and innovative spaces that are not the norm. Technology companies, in particular, must have a killer office space to attract savvy workers with zero interest in working in a cubicle from nine-to-five.

"The workplace is a reflection of an organization's brand, culture, and people, enhanced and supported by continually changing technology," says Melanie Delianides, Director of Business Development at office design firm Knoll. "The shift to embedding organizational culture and social experience is causing architects, designers and business leaders to re-evaluate how they articulate space and environment."[3]

Audacious online taxi company Uber used the design of its headquarters in San Francisco, California, USA, to reflect "the maturation of a start-up," says principal Primo Orpilla. The design concept was driven by an "ethos of populist luxury." Director of Design Denise Cherry describes how CEO Travis Kalanick was highly involved in the design process. "Nothing is there just for the look. For Travis, everything was about the Uber story."[4]

The use of materials throughout the office spaces reflects Uber's tiered rental options: marble, walnut, copper, and leather represent the high end, while polycarbonate and steel exemplify the mid-level. Office walls are adorned with stylized maps of Uber cities. "Kalanick insisted, right from the outset, on design, design, design — to play to the 700 employees as much as to visitors," writes Edie Cohen of *Interior Design* magazine.[5] The entire office experience is staged and orchestrated, from the gleaming black lobby to the pale gray and brilliant white of the reception area, complete with massive walnut table intersected by a slab of violet marble.

The workspaces themselves offer a range of amenities, seating niches, upholstered benches, and hickory work tables, punctuated by Eames chairs, copper-covered walls and, over the café, an impressive Lindsey Adelman chandelier. In the office's main lounge area, an enormous LED-based touchscreen maps Uber cars in all 100 cities that the taxi company serves. This continually updated, interactive video display exemplifies the role that data-driven experiences can play in telling a company's brand story in an architectural space.

Employees and visitors enjoy a different sort of data-driven experience in the Chicago offices of Brookfield, a global management group that handles US$181 billion of assets. The huge 50-foot screen in the waiting area of Brookfield's office is interactive. When someone walks by, it automatically displays various topics within Brookfield's portfolio. That person might not even notice. But if some keyword grabs his or her attention, and the person stops to read it, a motion tracker, similar to the Kinect motion sensing input device used by Microsoft for its Xbox games consoles and Windows PCs, cues the software interface to automatically unpack more information on the topic.

An understanding of the social dimensions of such an interaction is an important design consideration. The interaction design was carefully conceived to invite passersby to explore while minimizing the potential intimidation of having their activity (and possible errors) on very public display. "This is a casual, proximity-based interaction," says Campbell Hyers, CEO of interaction designer Control Group. "It's about giving someone pertinent information, but not making them look like a fool to get it."[6]

Taking it **to the streets**

Office buildings have exteriors as well as interiors, of course, and a building's exterior can do as much as an office interior to promote a company's brand. Office exteriors have a public or municipal dimension, making them much more community-oriented. Cutting-edge architecture and dynamic exterior lighting can make an office building act as a landmark in the city, and expressive designs can make a corporate brand stand out and be recognized.

Innovative Hong Kong architect James Law invented the concept of Cybertecture to provide "a symbiotic relationship between the urban fabric and technology." Pioneered in 2001, Cybertecture plays a role in the evolution of working spaces "by providing awareness and connectivity via seamless integration of technology into the fabric of space."[7]

One of James Law Cybertecture International's most interesting projects is Parinee I, a 21st-century office tower in the heart of Mumbai, India. This dynamic tower, 160 m high, which dominates the city skyline, provides ultramodern office space for a wide range of businesses, including creatives associated with the massive Indian film industry. The building is covered with diagonal façades at different angles, each of which features and LED screen for film and graphics projection.[8]

On the other side of the globe, in Lima, Peru, lighting designers Claudia Paz and Nicholas Cheung covered the exterior façade of the Banco del Crédito de Peru (BCP) headquarters with a large interactive public art installation. This installation has not only changed the city's skyline, it has also forged a unique connection between the bank and community by engaging city dwellers and creating a space for social participation.

BCP commissioned Paz and Cheung explicitly to translate their brand values of openness and transparency into a lighting design that would integrate seamlessly with the building's exterior glass curtain wall. "Our vision was to give people a new way of seeing, feeling, and experiencing their perception of self and the freedom to explore new sensations," said Paz. "We wanted to create a permanent installation on an urban scale instead of just a media façade."[9]

BCP Affinity is a three dimensional façade consisting of an LED canvas, an interactive LED outdoor podium with multi-touch sensors, and an interactive lighting control system. The façade consists of over 26,000 individually controllable full-color LED lightpoints in six layers. To enable interactivity, Paz and Cheung created a podium of LED panels that recreate the façade in miniature. Passersby choose from eight interactive shows that use both light and sound.

Multi-touch sensors in the panels trigger a network of interactive servers that remotely process the live input data. The content, which includes such effects as constellations, fireworks, and rain, instantly appears on the façade, in an area over 90 feet tall. "The idea was to prompt the client to create a public artwork intervention that contributes to the wider urban fabric," the lighting designers affirm. "And it is hoped that such key spaces could become a highlight for the extraordinary, as well as places for social participation."[10]

BCP, Affinity

Bright lights, big cities

Municipalities are also getting in on the branding trend, using the entire city as a canvas for promoting the city's image on national and international stages. City branding can accrue multiple benefits to the community and its businesses, including increased tourism, enhanced nightlife, urban regeneration, and safer and happier citizens.

Lighting for city branding can take several forms, from public lighting experiences on iconic bridges, façades, and monuments, to intelligent street and roadway lighting. The latter can help a city achieve its sustainability and resiliency goals, and is often part of a larger Smart Cities initiative.

Non-profit ILLUMINATE, the California Department of Transportation, and world-renowned artist Leo Villareal collaborated to create a living light display on the San Francisco-Oakland Bay Bridge, in celebration of its 75th anniversary. Turned on in March 2013, The Bay Lights — the largest LED lighting sculpture in the world — instantly became a source of pride for the community. It has also revitalized the city's waterfront economy, with local bars and restaurants reporting a 30% increase in business. Studies by a group of more than 20 leading independent analysts concluded that The Bay Lights boosts the regional economy by more than US$100 million annually.[11]

Originally a temporary installation, bridge officials agreed to maintain the lights on an ongoing basis if ILLUMINATE could raise the funds necessary to make the artwork permanent. ILLLUMINATE kicked off a crowdfunding campaign to raise the funds, and along with donations from larger donors, was able to meet the goal.

ILLUMINATE exists expressly to tell the story of San Francisco through public art experiences. "Response to The Bay Lights is so far reaching and profound that it has lit a path beyond itself," The Bay Lights website states. "Our highly aspirational mission of changing humanity's future for the better via public art — some would call it impossible — is a reflection of our core beliefs."[12]

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