Light Fantastic

In tomorrow's buildings smart lighting will provide a platform for data driven applications the like of which have never been seen before

> The marriage of LEDs and low power wireless technology offers so much potential the smart lighting industry is about to explode

In Short

The flexibility, efficiency and longevity of LEDs is driving the rapid replacement of conventional lighting

Wireless mesh network technology brings bidirectional connectivity that makes configuration, control and monitoring of smart LED lighting simple

Wireless mesh networking is complex and requires specialist companies to implement

Mass market adoption of smart lighting relies on educating customers about its benefits

The next stage for smart lighting is 'Lighting as a Platform', enabling the infrastructure to support advanced building management systems

Smart lighting is the most glamorous manifestation of the IoT. It perfectly melds the aesthetics, efficiency and longevity of solid state lighting (SSL) with the connectivity, control and scalability of wireless network technology. Such is the perfection of this fusion it's almost as if the two technologies underpinning smart lighting—LEDs and low power wireless—were developed as one.

In truth, the combination is entirely serendipitous; a fortunate convergence of two independent lines of enquiry both of which trace their genesis back to the turn of 20th Century. (See sidebar *From curiosity to commercial success*.) No matter, it's a marriage that offers so much potential that the industry is about to explode. For example, according to the U.S. Department of Energy (DoE), by as early as next year LED lighting will account for 77 percent of U.S. lighting sales. And analyst, IndustryARC, says smart lighting—wirelessly connected SSL—is rapidly replacing 'dumb' LED fixtures. The company says the global smart lighting market size was worth $6.87 billion in 2018 and is exhibiting double digit annual growth.

This growth is driven in part by LEDs' green credentials; the technology saves energy and reduces carbon emissions (and consumer bills). The DoE says LEDs use at least 75 percent less energy (and last 25 times longer) than incandescent lighting and, in the U.S. alone, by replacing conventional bulbs with LEDs, electricity consumption has been cut by 348 TWh and bills by $30 billion. Moreover, by not burning the fossil fuel needed to generate that electricity, 100 million tonnes of CO_2 emissions are avoided.

But smart lighting is so much more than a clean, efficient and sustainable technology. Because lighting is a fundamental element of the fabric of every building, the wireless technology built into each fixture can not only make it simple to configure, control and optimize the illumination, but also support a wide range of distributed sensors that help save even more energy, improve productivity and enhance building security.

However, while the technology is rapidly emerging, there are many hurdles to overcome before the analysts' forecasts become reality. Some of these are technical, others are a matter of consumer perception. But a group of pioneering companies are leaping these hurdles and smart lighting's graduation to the mainstream is coming closer.

GREEN WHITE LIGHT

LED lights have key advantages over both incandescent and fluorescent alternatives. The prime benefit is energy efficiency. A 100-W incandescent bulb radiates most of its energy as heat with just 5 percent converted to visible light; as a result, the device's efficacy is just 10 lumens (a measure of luminous flux) per Watt. Compact fluorescent lamps are better, with an efficacy of 40 lumens per Watt (lm/W) but the LED is best of all with commercial units producing about 100 lm/W. With lighting consuming around 20 percent of global electricity generation that efficacy makes LEDs a poster child for environmentalists. LEDs also last much longer than conventional light sources; typical operational life of 30,000 hours is common, which equates to ten to 15 years in typical use. In comparison, an incandescent bulb lasts up to 1000 hours while the best CFLs make it to 15000 hours. SSL's longevity also helps cut down on waste material—most of the materials can be recycled—and the devices don't contain the hazardous mercury common to CFLs.

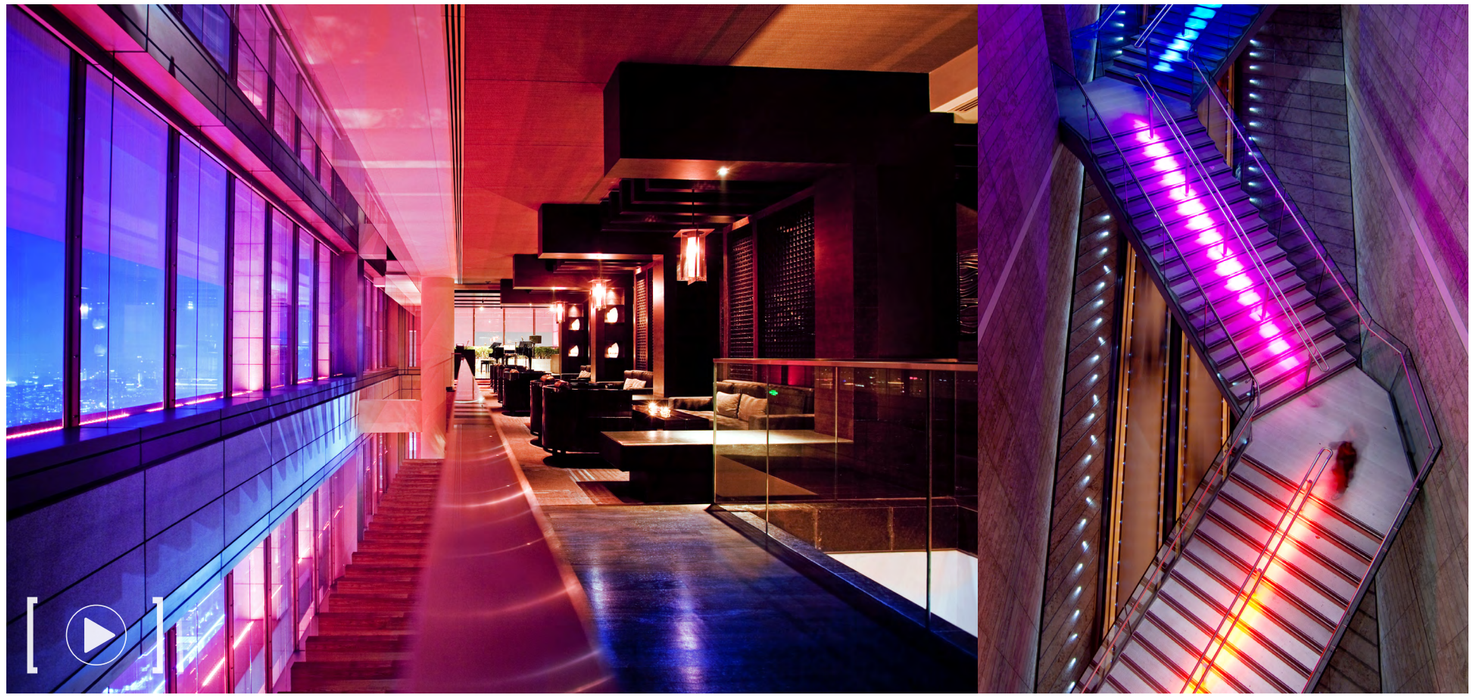
Compared to incandescent bulbs, LEDs run at lower temperatures (although not exactly cool; temperatures around the device's semiconductor junction can exceed 120°C) which allows for compact, novel fixture form factors which were previously not possible. So-called white LEDs (the devices at the heart of most commercial lighting) are typically formed using a blue LED as a "photon pump" surrounded by a specially formulated phosphor. Most of the blue light is absorbed by the phosphor and re-emitted as yellowish light while the rest passes through. It is the combination of blue and yellow that makes the emitted light appear white to the eye. Manufacturers tweak the combination of blue LED and phosphor to produce products with a range of color "temperatures" (from bluish-white "cool" lamps to yellowish-white "warm" ones). More sophisticated luminaires do away with the phosphor and

Cover Feature: Property Tech

instead electronically combine the light from red, green and blue LEDs such that the mix of their outputs can produce virtually any color of the visible spectrum.

LEDs aren't without drawbacks. They are more expensive than conventional lighting (although the price has plummeted in recent years) and tricky to dim. And because the LED at the heart of a luminaire is finicky, it requires complex electronic drivers to ensure a precise constant current/constant voltage power profile is maintained.

But these disadvantages pale when compared with the positives, and the momentum towards an LED illuminated world is unstoppable. For example, according to the International Energy Agency (IEA), global LED uptake has risen from a lighting market share of 5 percent in 2013 to 40 percent by 2018. The agency expects penetration to reach 90 percent by 2030.

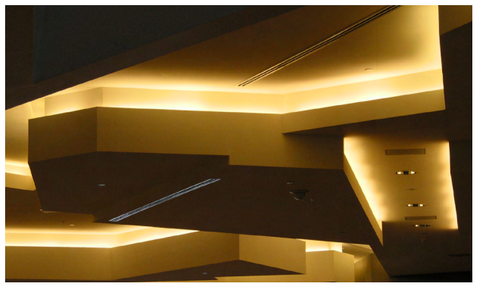


THE POWER OF MESH NETWORKING

LEDs are undoubtedly a novel technology, but it's when they're combined with wireless connectivity that things get really interesting. Low power wireless multiplies LEDs' advantages by endowing the devices with bidirectional connectivity such that they can be remotely configured, controlled and monitored. That means, for example, that light output can be tuned to exactly match ambient light conditions ensuring that productivity is increased, and energy usage is minimized. "[After we installed] a smart lighting project in a school in Durham, North Carolina, a flip of a switch allows a teacher to 'edit' the mood and change the intensity of the classroom," says Trevor Palmer, SVP Digital Lighting Networks with Acuity Brands, a lighting and lighting controls company headquartered in Atlanta, GA.

Wireless connectivity also allows sensors fitted to luminaires to monitor the occupancy of the workspace such that light levels (plus other services such as heating) can be automated to match the number of people using the room.

There are several competing wireless protocols for smart lighting but no clear market leader. Notable technologies include Bluetooth, Thread and Zigbee. "It's very important to support all the leading wireless technologies as a dominant protocol is yet to emerge for smart lighting," says Eirik Midttun, Technical Product Manager with wireless chipmaker Nordic Semiconductor. "Our wireless SoCs are multiprotocol devices so the OEM has complete freedom to select the protocol of their choice for their smart lighting solution, or even run Bluetooth LE concurrently with Thread or Zigbee if the requirement arises."



A manufacturer might want to take advantage of concurrent protocol support to, for example, use Thread for wireless connectivity between the lights but take advantage of Bluetooth's interoperability with smartphones—with their familiar touchscreen—for configuration. That advantage becomes even more important for mesh networks because the topology can be tricky to configure without the aid of an intuitive interface.

A mesh topology endows a network with a number of advantages – such as allowing devices within the network to communicate with any device on the same network using radio packets relayed via other devices and without recourse to a central hub. Such a system extends the range, flexibility and redundancy of smart lighting.

"Mesh networking is extremely beneficial," says Neil Salt, Managing Director of Gooee, a London-based automated building control platform developer and vendor. "It really helps in dealing with environmental interference, improves stability and provides options when installing, commissioning and running a system."

The Bluetooth SIG, promoters of Bluetooth, has developed a standard for building mesh networks using Bluetooth LE. Dubbed Bluetooth mesh, Version 1.0 of the specification was introduced in July 2017. The standard is based on expert knowledge in mesh technologies for smart lighting contributed by Krakow, Poland-based supplier of wireless lighting control systems, Silvair, and other companies.

Bluetooth mesh includes functionality that allows handsets to temporarily join the mesh network (via a so-called proxy node) to aid configuration of individual nodes and communicate with all nodes directly, saving the cost and complexity of a proprietary hub and interface.

Tech Check

Nordic's nRF52 Series presents ideal solutions for smart light OEMs. The SoCs offer Bluetooth 5.1 Direction Finding, Bluetooth mesh, Thread and Zigbee concurrent support, a stable hardware and software architecture, over-the-air device firmware updates and high temperature capability

According to Rafal Han, CEO of Silvair, the adoption of Bluetooth mesh has come not a moment too soon. "The standard is a milestone in the development of smart lighting – especially when it comes to security, scalability and ease of use," he says. "Ease of implementation is super important for fast adoption [and that's helped by] flexible and open solutions like Bluetooth mesh. It's true it needs to prove its reliability but that's already happening now."

"Bluetooth mesh is a key development and as a major supplier of wireless solutions to the smart lighting industry, Nordic was among the first to ensure its SoCs supported the standard," says Alf Helge Omre, Nordic Semiconductor's Business Development Manager for Lighting and InDoor Positioning. "And with our technology over-the-air software updates are easy, ensuring that over a long service life the chips can take immediate advantage of software upgrades as the protocols evolve. But smart lighting is not only about the software. Nordic's hardware is mature which helps underpin smart lighting's stability. In this market such stability is especially important because product lifetimes are generally much longer than in areas like consumer. In addition, a lighting fixture is a hot environment, so the OEM needs to ensure the selected wireless chip is tested and certified for operation at elevated temperatures."

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LIGHTING AS A PLATFORM

There is little argument that LEDs are the best choice for a greener future. But clean, controllable, long lasting illumination is just a tiny part of how wireless mesh networked smart lighting will influence that future. LEDs alone, while impressive, aren't smart; the intelligent part

Smart lighting on schedule

Bastiaan de Groot
CEO: Ingy

When I'm asked if the smart lighting industry has been slow in reaching mass adoption, I always think: how long should we expect an innovation or disruption to take before it reaches a critical mass? To paraphrase Amara's law, in the face of disruption people tend to grossly overestimate the short term possibilities of the technology, while grossly underestimating the possibilities in the long term, and this is exactly what is happening in the smart lighting world.

We have been talking about smart lighting in the true sense for more than a decade, probably longer, but people who suggest it's been slow in taking off, forget or ignore the technical readiness of the underlying technologies that needed to be ready for the disruption to take place. Although many of the required technologies for smart lighting—principally the sensors and the wireless connectivity—have been available for a long time, the performance and cost didn't necessarily support it, and only now are they readily available at performance and price level that's required to truly develop smart lighting on a mass scale. So yes, for someone who has been aware of this technology for a long time, it may seem to be going very slowly, but I believe the take-up is going exactly as expected for a disruption of this size.

The advent of scalable, self-configuring wireless mesh networks and the cost reduction of sensor technology has been crucial in reaching this point. Only with a full self-healing mesh can you get comprehensive building coverage without having to place central gateways everywhere and removing the need for a central controller is vital in achieving the necessary reliability for a solution for which no central point of failure should exist. Only a true mesh can deliver this. The next big challenge will be to deliver mesh networks that can scale and support the bandwidth necessary to deliver the full backbone for all the sensor data required for a smart building – not just lighting.

For plug and play, self-healing lighting control products and Cloud-connected lighting solutions that provide remote diagnostics of lighting-related services, we are now at a tipping point, and are really starting to see some major traction with customer projects being rolled out at scale. For products that use lighting as the digital infrastructure of the building, to offer services like indoor positioning, occupancy analytics, asset tracking, climate monitoring and the like, mass adoption will take longer, but it will be the most influential when it arrives. Lighting is everywhere, it is already powered, and if you use the latest wireless connectivity it is already connected, making it the ideal infrastructure to place sensors in your building. The value you create this way is far bigger than the value of lighting on its own. People will be stunned how quickly these solutions will get adopted, and how this will completely change people's smart lighting buying behavior.

of the technology is the wireless connectivity. And not just because that technology makes it easy to configure, control and monitor a lighting network.

Everywhere people go indoor requires illumination and therefore lighting fixtures. By design, these are positioned precisely to ensure even and complete coverage, they are safely out of harm's way, and typically plugged into mains electricity. That makes lighting infrastructure a perfect platform for an array of wireless sensors monitoring temperature, humidity and air quality – the things that determine whether or not a building is a nice place to be.

It's a platform that can simultaneously deliver both energy savings and additional services in the form of wayfinding, asset tracking, space utilization, and point of interest information broadcasts. According to the Bluetooth SIG's *Lighting as a Platform* report, while smart lighting can deliver as much as a 50 percent saving in lighting energy costs, the additional services enabled by the technology could be ten times more valuable than even the energy savings. That's got the commercial building sector seriously interested.

Because it's a simple step to transmit data across wireless mesh networks, building automation can constantly monitor and continuously make subtle changes to the environment to ensure staff are comfortable while saving money. "By analyzing occupancy data from the lighting control system, for example, you can typically save up to 20 percent of the heating by reducing the capacity of the HVAC based on the actual [number of people]," says Bastiaan de Groot, CEO of Ingy, an Amsterdam-based smart lighting and building control services company.

Moreover, with the advent of technology such as Bluetooth 5.1 Direction Finding, lighting fixtures could be perfect for mounting locators for asset tracking or indoor positioning systems. While Bluetooth 5.1 Direction Finding is yet to find its way into lighting installations, Acuity has helped Giant U.S. retailer Target equip its LED fixtures with wireless beacon technology. The beacons enable interaction with shoppers who opt-in to the store's Target app, helping them navigate their way through stores.

Elsewhere, Ingy has helped a hospital implement an asset tracking scheme for its medical equipment. "Without using the lights as beacons, the hospital would have to roll-out tens of thousands of anchor nodes — now they're no longer required," says Ingy's de Groot.

Gooee says it recently became the first smart lighting technology company in the world to win a project that connects more than 5,000 buildings to its platform. For the project, Gooee's Building Operating System will take control of inefficient, existing building systems to optimize both building and business performance. With almost 12 million square meters being maintained and serviced just a 10 percent saving on energy alone would recoup $132 million in costs over the decade long agreement.

And Silvair's solution has been implemented in locations in the Europe and the U.S. Examples include an office in Brussels as well as warehouses in Sacramento, CA.

By the Numbers

22.7%
Smart lighting CAGR from 2019 to 2025

Source: IndustryARC

75%
Energy saving by using LEDs instead of incandescent lights

Source: U.S. DoE

From curiosity to commercial success

Briton Henry Joseph Round is occasionally credited with discovering the "light emitting diode" as far back as 1907. But what Round—coincidentally an assistant of radio pioneer Guglielmo Marconi—actually discovered was the electroluminescence from a crystal of silicon carbide when it was subjected to a voltage.

It was Russian scientist Oleg Vladimirovich Losev who did much to bring LEDs to life. In a series of papers published up to 1930, he detailed the physics of an LED—formed from a silicon diode and generating light by the recombination of electrons and holes in the depletion region of the *p–n* junction—before his untimely death during WW2.

Then, in the early 60s, Nick Holonyak of Bell Labs (and other researchers, notably at GEC and IBM) were working on semiconductor lasers to power optical telecommunications when they chanced upon the red LED. Today, Holonyak is generally accepted to be the first person to extract visible light from a semiconductor device.

In the late 1980s and early 1990s Japanese researchers did the heavy lifting to invent and perfect the blue LED/phosphor combination used to create the 'white' LEDs that were the precursors of the devices used in today's lighting. But the luminosity of these white LEDs was still poor compared with conventional light sources; this lack of performance resulted in LEDs failing to gain a foothold in the commercial lighting market.

The technology received a boost in 1999, when solid state lighting visionary, Roland Haitz, produced a paper that suggested LEDs could reach an efficacy of 200 lumen per Watt and reduce worldwide energy consumption devoted to lighting by 50 percent over the next few decades. The impact of Haitz's paper was to raise awareness of the energy saving potential of LEDs to a wider audience and encourage chip makers to invest in the technology.

Today, high brightness LEDs are perfectly complemented by wireless technology. Low power wireless protocols such as Bluetooth, Zigbee and Thread are now routinely incorporated into commercial lighting solutions. Supported by wireless tech, the next phase of the lighting evolution will be 'Lighting as a Platform'.

EDUCATIONAL CHALLENGE

Acuity, Gooee, Ingy and Silvair are the vanguard of the smart lighting industry. The challenge for such companies is to impart the vision of lighting as a platform onto the mass market. And it's going to take a determined effort to educate a conservative audience.

"We shouldn't expect smart lighting to be adopted overnight," explains Gooee's Salt. "Take up of any new technology over the past two decades has been slow. For example, when LED lighting was launched the industry took a while to move over from halogen. The key challenge is to get the right people in a business to understand and consider the benefits of a wirelessly connected lighting system, trusting it can perform to the expected demands and that it actually does what's being touted."

"The customer clearly understands the environmental aspects of LED lighting but doesn't really understand what smart lighting promises," says François van Burk, CEO of Dutch conventional and smart lighting installer, Building Bright. "Today, a simple system whereby the lights automatically dim as daylight increases is considered smart by some. But of course, it's far from it."

These are views echoed by Silvair's Han: "Educating the market is a long process which requires the commitment from all the lighting industry stake holders. I believe many non-lighting specialists understand the benefits but are still confused about the advantages of using data generated from [the] networks." He says the key challenges preventing rapid adoption are complexity, difficult installation, reliability, scalability and security.

Caution remains the byword for the commercial sector. This is perhaps understandable particularly as wireless connectivity inevitably introduces security concerns. "There is fear of the security implications," says Building Bright's van Burk. "Customers are waiting for big companies such as Google to endorse smart lighting and say it's secure before they move forward. But then corporate customers are cautious about any connected technology, not just smart lights."

Gooee's Salt concurs, saying security has definitely caused companies to stall the adoption of smart lighting. "It is a major concern," he says.

But there's cause for optimism. "The industry is still in the realm of educating the systems integrators," says Acuity's Palmer. "But while the conversation starts in energy savings it does progress quickly to 'what else can we do?'."

The answer is a lot more than customers might imagine. The smart capability of a wireless mesh networked lighting system endows it with almost unlimited functionality but that comes at a price: A high level of complexity.

Acuity's Palmer explains that a typical smart lighting system includes: Connected lighting (the LEDs, drivers and sensors); controls (to look after both the lights, sensors and other systems such as HVAC); edge gateways (to run IoT applications such as location services); software services (to support capabilities such as indoor navigation; and a building management platform (an OS to look after overall supervision, analytics and Cloud connectivity).

According to Gooee's Salt, such complexity initially made the language surrounding smart lighting overly technical, but he says people now understand more, while companies like his own have found techniques to "abstract the complexity" and better ways to communicate the benefits. Further, he says: "There are now regulations and laws in place, along with standards to reassure companies and individuals alike. This is slowly helping build trust in IoT systems and connected devices [such as smart lights]."

That trust will take time to grow and the complexity is such that smart lighting will continue to suffer growing pains. But the significant change of the last several years is that, originally designed independently and decades in gestation, the underlying technologies of LED lighting and low power wireless have coincidentally matured and reached acceptance in the mass market. And now these two technologies have converged to not only revolutionize lighting but also provide a ready-made platform for data driven applications the like of which have never been seen before. To paraphrase SSL visionary, Roland Haitz, smart lighting today is where the Internet was 30 years ago. Back then we couldn't imagine what the Internet was to become and the same is true of smart lighting. But what's more certain is the future for the technology will be as much about information as illumination.

> Smart lighting is not only about the software – the hardware has to be mature too because it underpins smart lighting's stability