MOST INNOVATIVE COMPANIES 2014

HOW PHILIPS ALTERED THE FUTURE OF LIGHT

EIGHT SURPRISING LESSONS IN INNOVATION FROM PHILIPS'S 50-YEAR EXPLORATION OF LEDS.

BY JON GERTNER

Not far from its Amsterdam headquarters, at the end of a hallway on the ground floor of a squat modern office building in the small Dutch city of Eindhoven, Philips has set aside space for what it calls an Innovation Lab. It looks a lot like a living room, with a large-screen television, soft leather couches, and a plush beige carpet. There are no windows, and when the door shuts it seems easy to imagine nodding off to a soccer game and awakening in what you think is not a cozy den in the middle of Holland but a high-end apartment in New York or London. Of course, that's the point. It's incongruous that Philips, a global leviathan with offices in 60 countries, 114,000 employees, and sophisticated electronics products that range from $40 DVD players to $1 million MRI scanners, would associate such an ordinary space with anything groundbreaking. And yet this room was the incubator for a company-disrupting (and, possibly, world-changing) idea.

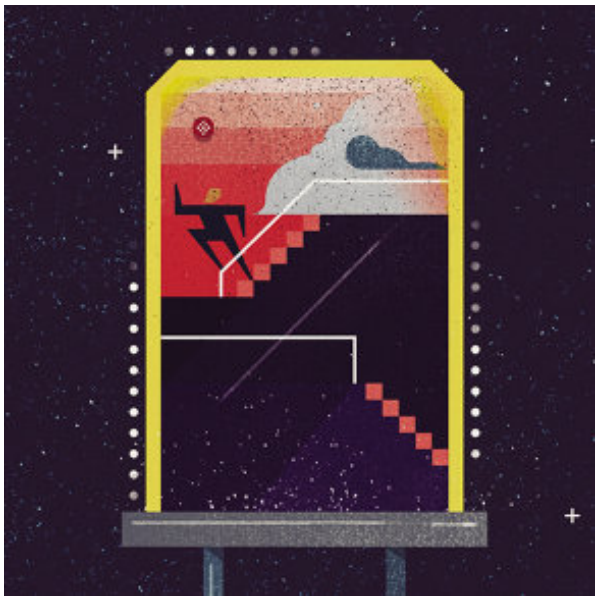
The Innovation Lab is banal so that Philips can gauge the effect of something radical, in this case the impact of new types of LED lights--lights that turn cerulean blue or sunset pink; lights that dim or brighten wirelessly; lights that pulse along with the rhythms of speech at a command given from the iPad of George Yianni, a young, bespectacled engineer with dark, tousled hair and a casual manner.

In 2011, Yianni's superiors in the lighting division asked him to create a device that, in Yianni's recollection, "would make a splash." They gave him 11 months. So he started spending most of his days, and many of his nights, in the lab trying to perfect the applications

for Hue, a wireless lighting system that went on sale just over a year ago. "What we really wanted to do with Hue was change how people think about lighting," Yianni tells me. "We've been making lighting products for 120 years, and until last year, for the home, all they did was turn on and off. We thought: Why not do more with it than just turn it on or off?" Hue allows you to "tune" your lights to up to 16 million different colors. You can control them remotely so that you don't walk into a dark house. You can adjust the color or intensity to increase concentration or relaxation, based on years of studies on the effect of light on human behavior. Hue can even produce gentle reminders, so that your hallway lights automatically turn blue on a rainy morning (Bring your umbrella today) or so your house lights dim steadily beginning at 8 a.m. (Time to catch the train). Thanks to LEDs' ability to accept digital signals, in other words, home illumination isn't only about seeing or feeling better. It is an atmospheric conveyor of information, too.

When I first heard about Hue last year, I wondered if it was just another luxury product for those eager to jump on the new-gadgetry bandwagon. This turned out to be correct in some respects--at around $200 for three bulbs and the hub that links them to your phone or tablet, Hue is not cheap. Yet I soon came to see this as a terribly narrow view of the product. Hue is the culmination of about 50 years of innovation with LEDs, or light-emitting diodes, a technology

HOW THE LED ALTERS THE FUTURE



SAFETY
Thanks to the customizable nature of LEDs, they can provide better light where it's needed--helping pedestrians and drivers navigate sidewalks or twisting roads.

pioneered in large part by Philips that might prove to be one of those once-in-a-lifetime ideas that we're always on the lookout for but rarely identify until after the fact. For Philips, LEDs are the vehicle for its next-generation innovations and the engine for its future growth. "Right now, 30% of what we sell are LEDs," Eric Rondolat, CEO of Philips Lighting, tells me when we meet in his Amsterdam office, situated in a sleek high-rise tower next to the Amstel River. "We believe it will be 45% to 50% in 2015." That jump, which represents approximately $2 billion in sales, shows just how rapidly Philips's business is shifting. And yet, in terms of its potential impact, LED is a fairly young technology. So far, early buyers are drawn to the durability of LEDs (lasting not just years but decades) and their extraordinary energy

DURABILITY AND EFFICIENCY
Unlike incandescent bulbs, LEDs will last decades--many are rated for lives of 20 or 22 years. The bulbs use a fraction of the energy of older technologies, which means they'll have a profound impact on carbon dioxide emissions.

CALM AND CONCENTRATION
Based on Philips's research in Europe, LEDs can be set to wavelengths that appear to measurably improve education environments. The lights can boost concentration or alertness, or aid in relaxation.

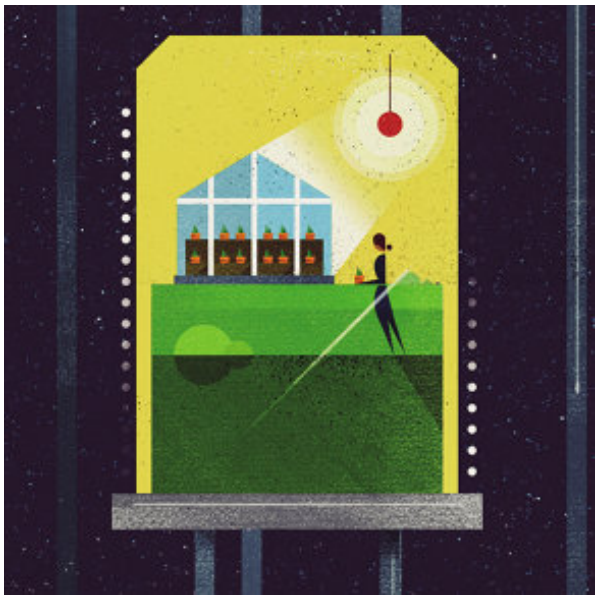
efficiency (using just 15% of the electricity of an incandescent bulb). This is already sparking global changes. "If you look at the energy savings, it's really quite stunning," says Kathleen Hogan, a deputy assistant secretary at the U.S. Department of Energy. The DOE estimates that LED technology has the potential to reduce by half the amount of electricity used for lighting in the U.S., which would save the country about $250 billion over the next 20 years and reduce carbon dioxide emissions dramatically.

But environmental impact is just the starting point for LEDs. Philips execs including Yianni and Rondolat believe that Hue signifies the end of the beginning of LEDs. "Okay, we understand LEDs are more energy efficient," says Philips's chief strategy

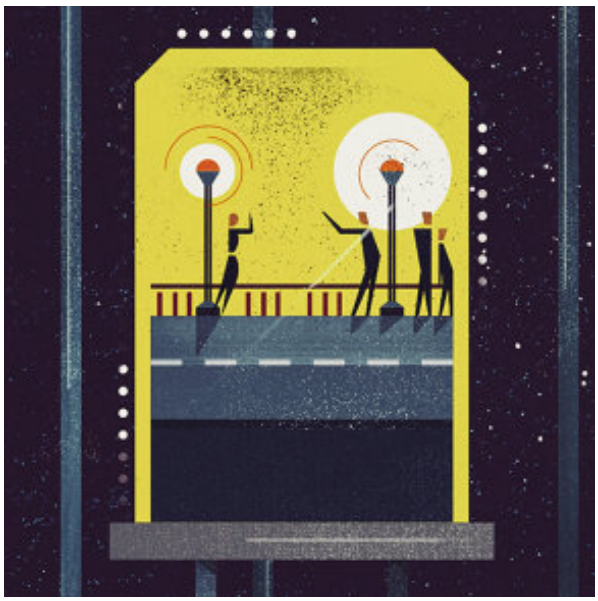
HEALTH AND WELLNESS
Specific light recipes have been shown to speed patient-recovery times in hospitals. Meanwhile, new home medical devices are reaching the market in Europe that utilize intense blue LED lights to ease back pain.

COMMAND AND CONTROL
Due to their digital and connectable nature, LED bulbs--such as Philips's Hue--can be accessed and controlled from anywhere there's an Internet connection, via a smartphone app.

and innovation officer, Jim Andrew. "But it really gets interesting when you start thinking about all the things you can do with lights when you switch from analog to digital." In a future where all lights are LEDs, lighting fixtures as we know them--with a screw-in bulb and power cord--may cease to exist, replaced by something far more futuristic (glowing walls, say, or glowing carpets) or, better yet, something wholly naturalistic, such as permanent "skylights" that change in color and intensity as the day progresses. At Philips, they're asking: How far can the technology progress beyond just saving energy and more creatively illuminating a room? Can LEDs improve your health, your sleep, your life? Can they ease pain, revolutionize agriculture, boost retail sales, reduce traffic accidents, improve urban safety?



URBAN FARMING
In horticulture, plants respond differently to various light wavelengths. Tailoring the output of LEDs for greenhouse growing has already been shown to increase crop yields.



SENSORY INTELLIGENCE
LED lights fitted with sensors can automatically know how much illumination is needed, and where it should be directed. The lights will adjust to a crowded party or to a dark parking garage.

For a company that may well be undermining a lot of its own sales (Who needs to change a lightbulb when your LED lamp lasts 22 years? And what will happen to all those "How many people does it take" jokes?), the answers might lead to its next great revenue stream. "This technology," CEO Rondolat insists, "is limitless."

TURNABILITY
Allowing employees to create personal lighting environments that vary in color and intensity could boost job satisfaction and (quite possibly) productivity.

[Illustrations by Dan Matutina]

To Andrew, the key to the potential of LEDs is that they can be both connected and intelligent. "There aren't many things where the measure of what's connected can be in the billions," he says. He lists cell phones and computers, but soon lights as well. "That's just a world that we were never really in," Andrew says, "so people don't even know the questions to ask."

Well, here's one: How did Philips take the LED to this point, and where does it go next? Which leads to another: If the LED happens to be much more than just a better light--that is, if it happens to be an innovation, like the PC or cell phone, that alters the world in a significant way--what can it teach us about how big innovations happen, and why?

1. To understand where the LED is going, it helps to understand where it came from. An LED is not a lightbulb, really--it's a light source, tiny and not much larger than a pencil dot, lodged deep within a larger package of plastic, metal, and glass that has been constructed to resemble a lightbulb mainly because consumers still prefer a familiar, time-tested shape. If you were to crack the glass top off a Hue bulb, or any Philips LED bulb, you would see anywhere from 6 to 26 small LEDs embedded within the chassis. Each of these LEDs are tiny sandwiches of semiconducting -

materials that, when connected to a power source, emit a stream of light. Without a glass cover to soften and disperse their emissions, LEDs are too glaring to behold. Indeed, in a naked state, the LEDs for a soft-white bulb usually appear as an unpleasantly piercing blue, or an exceedingly harsh white. An uncovered Hue bulb is a bit more varied but still harsh: Blue-white LEDs are joined by several red and green LEDs. These lights are what combine in various ways to create millions of colors.

In the beginning, the LED came in one color only--red--and was barely functional. Invented by Nick Holonyak in the early 1960s at General Electric, the first LEDs were seen as a scientific breakthrough but not yet a consumer product. The notion that this would one day be the world's fundamental lighting technology would have likely seemed absurd at the time. By the 1970s, red LEDs were beginning to be incorporated into clocks and other appliances. Yet what really changed things was the 1994 invention of the blue LED by Shuji Nakamura at Nichia in Japan. "The blue LED was the critical invention in the industry," says Pierre Yves Lesaicherre, CEO of Lumileds, the California division of Philips that makes the LEDs for Philips's lighting products. "It allows us to make white light. You can't make white light out of a red LED."

In fact, lighting engineers soon realized they could coat or shroud the blue LEDs with a material known as a phosphor and transform the color from blue to white. This discovery suggested that, in theory, blue LEDs could be adapted as replacements for ordinary lightbulbs. That is, if they could ever make it out of the lab. "Now an LED is so blinding that you can't even look at it," Lesaicherre explains. "But in the early days, the scientists here would make an LED, go in a dark room, and yell out, 'It lights up!' They were so excited." All of which is to say that an invention is not the same as an innovation. At the start, it is very difficult to predict whether a breakthrough can evolve into something that will actually change the world.

2. If the LED wasn't quite an innovation in the early 1990s, then what made it potentially revolutionary a decade later? Early on, the challenge for the LED, as with any fledgling innovation, was straightforward: It must do something either better, or cheaper, than the existing product it is trying to displace. To look at the future of light in the mid-1990s was to see that the LED did neither.

It was expensive, hard to make, dim. Yet even then, a few people saw the early trends and predicted that the technology might be able to achieve astounding gains, given the right amount of research, funding, and time. One of these people was Roland Haitz, who formulated a statistical rule for the rapid improvement (and steadily dropping costs) of LEDs. What became known as Haitz's Law would eventually be seen within the LED industry as having the same kind of prognosticating power that Moore's law had for the computing industry.

In 1999, Haitz and several scientists collaborated on a landmark paper that made the case for a national research program to hasten the development of LEDs. The scientists maintained that LEDs might eventually be able to achieve a new benchmark in lighting--a measurement pegged as 200-lumens-per-watt--that would be twice as efficient as fluorescent lamps and 10 times more efficient than incandescent lamps. Such an accomplishment would not be trivial. "This new white light source," they wrote, "would change the way we live and the way we consume energy." The authors calculated that with such a bulb in widespread use, the worldwide amount of electricity consumed by lighting would go down by 50%, and the total amount of electricity consumed worldwide would go down by 10%.

So the main reason for investing federal and private-sector dollars into LEDs--which is what eventually transpired, hastening the work at Philips and other companies--was the tantalizing possibility of immense gains in energy efficiency. "Our instincts when we wrote that paper were, 'Yes, this could really happen.' This is really a big deal in energy consumption," Jeff Tsao, a scientist at Sandia Labs and one of Haitz's coauthors, says. "But we also wrote that paper because the challenges were really daunting. And a lot of people were really skeptical." It turned out that they had good reason to be.

3. Software is different from hardware. Software spreads rapidly and cheaply, and often almost effortlessly; hardware like the LED does not. In the early 2000s, Philips believed that the product could only achieve scale or impact--the very definition of an innovation--if its manufacturing costs could be reduced and its quality greatly improved. The only way to get there was to gain one

modest step at a time. Thus, Philips had to improve manufacturing processes, experiment with new materials, and make a host of improvements to help the LED surpass existing lighting technologies. And it had to imagine all the possible applications, no matter how small, because of a strategic reality: A radical new product will need to infiltrate markets at the margins before it can claim the center. To make the lighting device better, or cheaper, or both, Philips and its competitors had to search for crevices and footholds. The company also looked to what history could teach it. For instance, long before the transistor, probably the greatest innovation of the 20th century, was used in small radios or computer processors, it made its debut in hearing aids.

Philips first began to scale up by successfully incorporating the technology into cars--brake lights, especially--and also in traffic lights. The product's durability and efficiency was the selling point; the fact that repair crews wouldn't have to change traffic lights as often was a bonus. For consumers, meanwhile, the notion in 2008 that LED lamps might take the place of a common 60-watt incandescent bulb still seemed unlikely. That is, unless you might consider it a deal to pay, say, $50 for a mediocre lightbulb.

4. How to bring the cost down further? How to do it faster? With novel hardware, it often requires the resources of a large company to support a product during the long haul preceding its mass manufacture. At the same time, government policy and funding often help push a breakthrough innovation into the market. It's worth remembering that Google actually began as a Stanford Library project funded by the National Science Foundation, and that Tesla was only able to build its flagship Model S thanks to a huge federal loan allowing the company to refurbish an old GM factory in Fremont, California. LEDs enjoyed government largesse too: a decade of research funding that helped improve the technology, and legislation in dozens of countries resulting in policies to halt production of incandescent bulbs, thus clearing out market competition.

In the U.S. especially, another valuable boost came in the form of a $10 million prize--the L Prize, it was called--sponsored by the DOE in 2010. The DOE's challenge was for a private company to build a 60-watt replacement bulb with LEDs that was far better than anything in existence. The bulb could use only 10 watts or less

to produce 900 lumens of light, and it would have to emit a pleasing glow as judged by several standard industry measures. Philips's global R&D team spent nearly a year on the project. In the end, the company was the only one to submit a design that met the L Prize criteria.

The victory seemed to prove that achieving the "better" part of the better-or-cheaper challenge was doable. The L Prize demonstrated that a Philips LED bulb could now provide light that was just about as good as an incandescent and measurably better than a typical compact fluorescent. But the "cheaper" aspect was still a problem. Even in 2010, the prices of Philips's 60-watt LED bulbs, at about $40, were still stratospheric.

5. Human beings have a tendency to underestimate how long it takes for a scientific breakthrough to become a practical innovation. Consider the silicon solar cell, for instance, the ancestor of every photovoltaic panel in the world: It was on the front page of just about every newspaper in the country when it was unveiled, in 1954, as a device that would forever change how we generate electricity. But in 60 years, solar power has achieved only a small part of that promise, in large part because its costs have dropped so slowly over time. The LED, with origins in the early 1960s, has progressed only slightly faster. But what likewise seems true is that adoption rates can change quickly, just as they did with smartphones. As costs plummet and quality improves, a new technology can suddenly achieve an accelerating, global popularity.

In Lesaicherre's office in San Jose, a display traces the evolution of the 60-watt-equivalent Philips LED bulb. With each passing year, the designs are increasingly sleek. More striking is the descent in price. In 2010, a bulb that used 12 watts cost $39.97; in 2011, a similar bulb cost $24.97; and in 2012, it cost $22.97. By 2013, the bulb used only 11 watts to achieve the same output of light, but cost $19.99. "We don't show it here," Lesaicherre notes, "but the latest generation of lights went to $15, then to $12, and then to $8." The price drops reflect Philips's ability to build better LED components for less cost, as well as its ability to use fewer high-powered LEDs (or, in some cases, more lower-powered LEDs) in each lamp. At this point, Philips estimates that LEDs are improving

by 15% annually in terms of light output while decreasing about 10% annually in cost. The main question now is whether consumers will refuse such a deal: a lamp that pays for itself in a few years in energy savings and lasts 15 years beyond the payback.

6. So efficiency and economics can explain why LEDs will soon infiltrate our homes and offices--but not how the technology might subsequently evolve. The reasons behind the initial appeal of an innovation don't predict the range of problems it will someday solve. The transistor, for example, was developed as a new kind of amplifier and only later became the main component in computer processors; the laser was developed for communications, but now does everything from reading DVDs to assisting surgeons. Or consider the early cellular-phone systems, which were first deployed in Chicago in the early 1980s. The notion that such phones would evolve into pocket supercomputers that organize social life and global commerce was unthinkable to all but the most imaginative futurists. Phones were meant for conversation.

THE SECOND WAVE OF LIGHTING WILL INVOLVE HARNESSING THE INTELLIGENCE THESE DEVICES CAN CONTAIN--SOFTWARE AND SENSORS THAT CAN ALLOW LEDS TO UNDERSTAND WHERE LIGHT IS NEEDED.

What comes next for LEDs? To Bob Karlicek, a professor of electrical engineering at Rensselaer Polytechnic Institute, the "second wave" of lighting will involve harnessing the "intelligence" these devices can contain--software and sensors that can allow LEDs to "understand" where light is needed, and at what intensity and color. But the wave likely goes beyond that. LEDs' "tunability" (recall Hue's 16 million colors) can make them useful in areas such as horticulture and urban farming. "We've sold lights to greenhouses forever," Andrew, Philips's chief innovation officer, tells me. "And you could make the light better, stronger, but it was still a light. Now you come along and say: We can put in LED lights with the correct light recipe for a given crop.

And growing a tomato, and what optimizes a tomato, is different from what optimizes a strawberry. And now you can change the intensity, the color, and, if you actually optimize the recipe, you can get higher yields."

You often hear the phrase light recipe around the Philips offices.

It's used as readily to describe applications for plants as for human beings. For the past 100 years, scientists have studied how artificial lighting affects humans, but mostly in the realm of white or fluorescent light. The LED opens things up. The research is still at an early stage, but Philips has already demonstrated in academic studies that certain wavelengths of light, delivered by LEDs, can shorten hospital stays for patients by as much as half a day. And they seem assured that special LED light recipes will soon be available to influence our circadian rhythms in a beneficial way. (Circadian rhythms are known to have an impact on sleep, obesity, and even cancer.) On Hue, some light recipes already offer settings so users can "relax," "concentrate," and "energize." The descriptions arise from Philips's research on how settings in schools can improve student concentration, and how particular wavelengths have a relaxation effect. They're not the whim of an app designer.

7. Listening to Philips executives map out the future can lead to a realization: Older digital technologies--the Internet, for instance, or smartphones--accentuate the impact of newer digital technologies, such as the LED. This is most apparent in a product like Hue. Internet connectivity makes the product controllable by smartphone, but also endows it with a vast capacity for improvements. "You could buy it now and it will keep getting better," observes Yianni, "because the evolution is now more in the software and in the app." As Karlicek puts it: "Lighting took the 20th century off. Everybody was working on microprocessors and things like that." The upshot, adds Karlicek, is that with so much work going into lighting now, developers can piggyback on other technological gains of the past half-century.

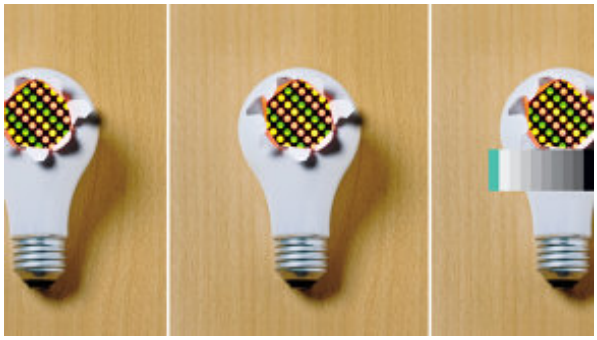
"AN EMPLOYER COULD ADJUST ITS OFFICE LEDS AND TRACK CHANGES IN EMPLOYEE TURNOVER, OR PRODUCTIVITY."

Big data, the buzziest of recent trends, plays into the LED future, too. Because LEDs are controllable and connectable, they can follow instructions from remote sources. But they can also relay data back. As Andrew tells me, "We can control how much light, the color of the light, the intensity of the light--almost any dimension. And because you do that, you can get more and more refined in your measurements." Everything, as Andrew explains, can then be analyzed by the question: If you use light recipe x, then what

happens to y? In other words, what happens to your store revenue, or foot traffic, or your holiday sale merchandise, as you tweak the illumination? A store owner could track how a certain lighting choice or intensity influences sales of scallops or neckties; she could do it by the minute, conduct a rapid data analysis, and make improvements as needed, or have them done automatically. A city with outdoor LED lighting could track accident rates on highways based on intensities or colors of light, or monitor crime rates in neighborhoods where LEDs, fitted with sensors, respond to foot and car traffic and brighten as the sun goes down. An employer could adjust its office LEDs and track changes in employee turnover, or productivity. In the end, the LED may be just as much about information as about illumination.

8. There is a downside to every innovation, and LEDs are no different. What if your company's main product is something that effectively never needs replacing? And what if it will soon become a low-cost commodity? Disruptive innovations don't just disrupt markets or change the way people live; they disrupt old business models, too.

There seems to be a consensus within Philips that the shape, color, price, and functionality will soon make the LED device as common as the incandescent bulb. Yet there also seems to be a consensus that the market for the devices will rise steadily until about 2019 or 2020 and will then level off or drop from saturation. "Clearly, after that there will be a significant opportunity as well as a challenge," Bruno Biasotta, the CEO of Philips Lighting Americas, says. Readying itself for a post–2020 shakeout, the company must bet on what will differentiate its business. The fact that Philips has done more to move LED lighting forward than any other firm is small comfort. History is littered with companies like BlackBerry that were destroyed by the technology they helped unleash.



There may indeed be large opportunities for selling LED products--physical stuff--as our lights and lamps evolve. At Philips's R&D center in Eindhoven, a vast

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campus of modern buildings fringed by small groves of birch trees, a team works in a large warehouse on the development of enormous assemblages of glowing panels, covered with light fabric and programmable to virtually any recipe or image--a rising sun, say. Across campus, a different team works up next-gen fixtures to capitalize on LEDs' small size and flexibility. What if your salad bowl were luminous? Your tabletop?

Still, the larger challenge to Philips is a future in which lighting ceases to be a physical product and is viewed more as an application. In many respects, the company's future depends on this transformation. Light could increasingly come to resemble a utility, like water or gas, whereby a company like Philips builds the infrastructure to provide it where it's needed, and then gets paid for it. A client--a small town, for instance, that needs new streetlights--could offset that cost via the energy savings made possible by LEDs. "Why should a city or a business buy all the capital around lighting, anyway?" asks Andrew. Cities don't want to invest in light poles or electricity. "What they really want to buy is light."

In a conversation in his Amsterdam office, Eric Rondolat, the global CEO for lighting, pushes the idea even further. While it's true that new technologies become commodities as they get cheaper and better, he asserts that digital lighting will allow for a product that can be decommoditized, too. In the future, says Rondolat, "you can select a light because you want a given application." Selling LEDs would thus be selling not an output but an outcome--growing certain kinds of fruit in an urban farm under an optimized wavelength, so as to increase yields; outfitting hospitals with customized light recipes so patients undergoing MRIs are more relaxed and imaging is therefore improved; providing schools with LEDs to help students settle themselves when the teacher needs to speak. The company that understands outcomes and applications will be the company that thrives.