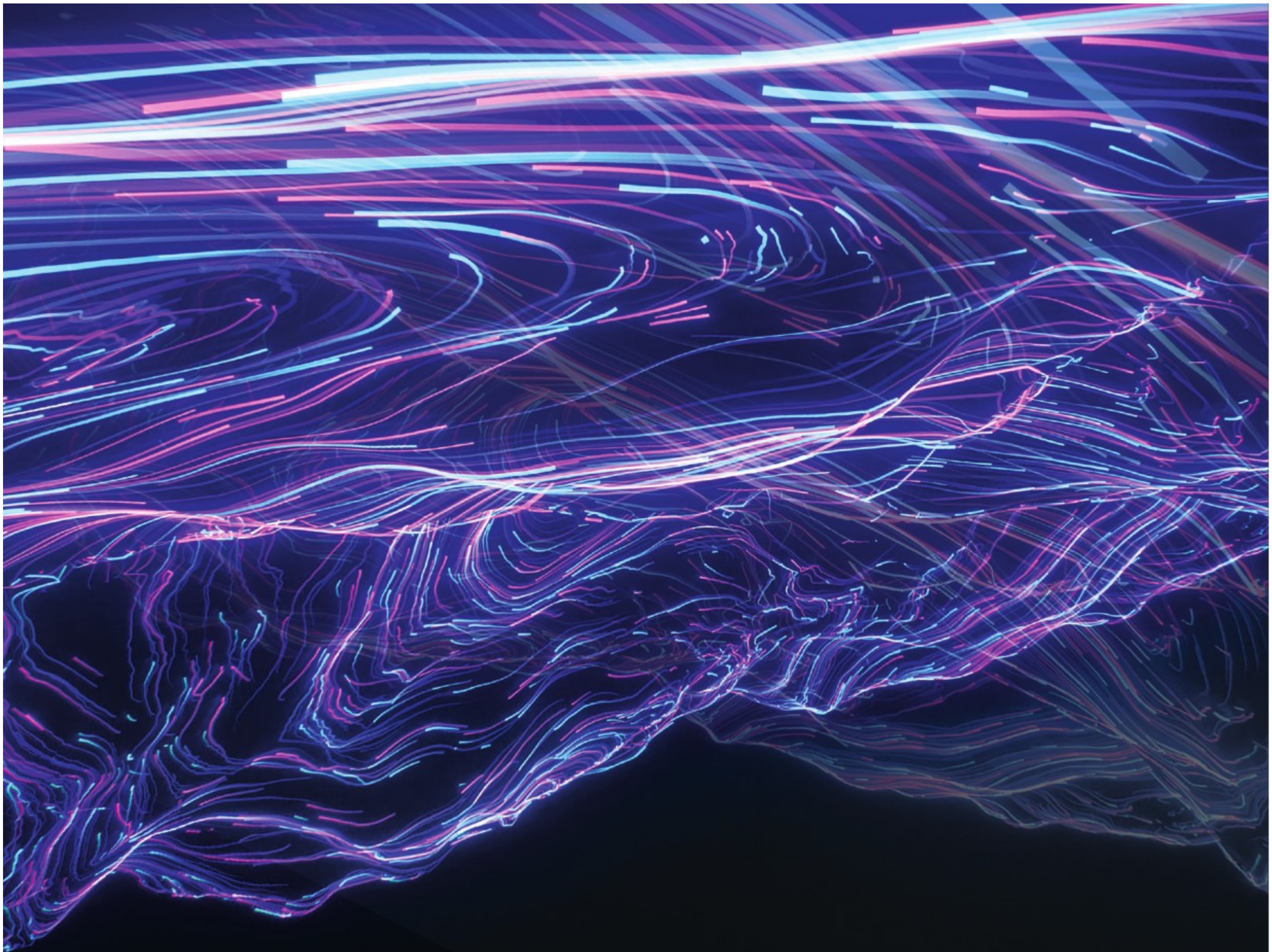


ENVIRONMENTAL *factors*

SUSTAINABILITY BENEFITS OF UV LED

by Cassandra Balentine

Ultraviolet (UV) light curing is used to cure or dry inks, coatings, and adhesives in a variety of industrial print applications. UV lamps are traditionally powered by mercury to produce heat, then light. However, the availability of light-emitting diode (LED) powered lamps offers an arguably more environmentally friendly alternative as solutions are able to convert electric energy directly into light.

UV LED solutions offer many sustainability advantages. These come in the form of lower energy consumption and the elimination of mercury and ozone production, no harmful solvents or volatile organic compounds, and fewer parts.

COMPARATIVELY SPEAKING

When comparing traditional UV lamps with UV LED, two positive features stand out—waste and energy reduction—both of which have environmental benefits.

Pollution Prevention

One prime benefit of UV LED technology is the fact that it does not contain mercury.

"Because of the dangers of mercury, the world is moving away from using it in industrial processes. Conventional UV lamps contain mercury, but UV LED modules do not. Conventional UV lamps can break and leak mercury into the environment, but LED cannot," shares Jonathan Fore, commercial lead, Baldwin Technology's AMS Spectral UV division.

Further, when conventional UV lamps are powered with enough energy to arc, they produce a harmful gas called ozone. "The ozone must be exhausted away from the curing system to prevent harm to humans working on the production line. LED does not produce ozone, which means less equipment is needed to run LED and less chance of harm to people and the environment," offers Fore.

"Studies have shown that in certain applications, replacing mercury lamps with UV LED lamps can lead to 20 tons of carbon dioxide reduction per product annually. With UV LED, there is no need for fume extraction units to remove the harmful gases and ozone generated by mercury vapor UV lamps. Mercury poisoning causes damage to the central nervous system, kidneys, and many other organs," explains Stacy Hoge, marketing communications manager, Phoseon Technology.

Utilizing UV LED lamps instead of mercury vapor UV lamps also reduces waste. "Conventional mercury arc lamps have a short lifetime and need to be replaced every 1,000 to 1,500 hours, generating a significant amount of bulb waste. UV LED curing lamps extend beyond 60,000 hours, if maintained properly. Upgrading to UV LED technology eliminates these bulb replacement costs, offering significant environmental benefits with the elimination of toxic mercury into the waste stream," she continues.

Petra Burger, process development, Dipl.-Ing. (FH), Dr. Hönle AG, points out that mercury is recycled and used for new processes.

Energy Savings

In addition to environmental benefits, financial advantages come in the form of energy savings.

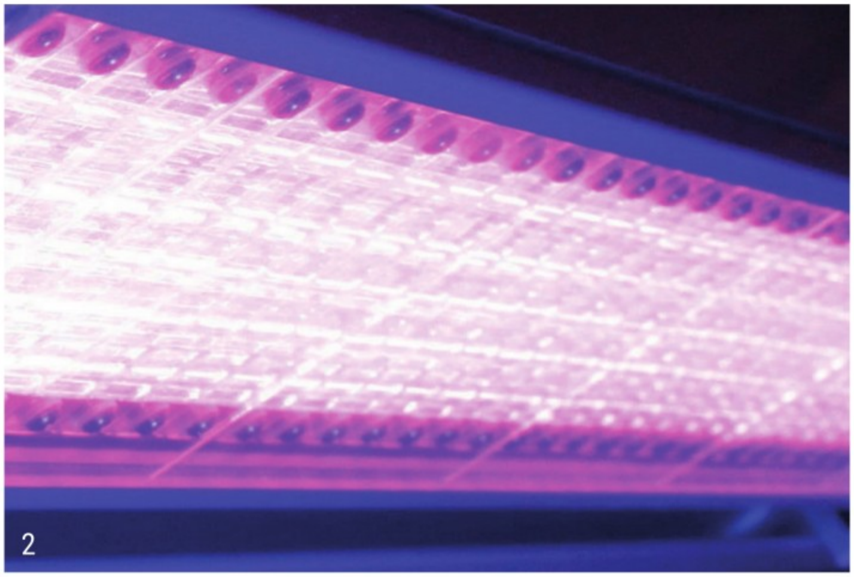
"With traditional UV curing processes, the tremendous heat associated with mercury vapor UV lamps require a significant amount of electricity to operate. UV LED technologies provide energy savings up to 85 percent compared to traditional mercury vapor UV lamps," states Hoge.

Bob Griesenbeck, UV/LED product specialist, Baldwin Technology's AMS Spectral UV division, points out that LED systems power on only when needed and are immediately ready to cure, versus more traditional arc-based lamps, which remain on throughout production and require an initial warm-up period that slows production and reduces efficiency.

Burger agrees, also noting that because UV LEDs do not need a heating phase, they can be switched on and off in short cycles, saving energy. "And, as each UV LED of a curing unit can be controlled separately, the irradiation area can be perfectly adjusted to the individual application," comments Burger.

"The long life of LEDs and their lack of conventional lamps, reflectors, and shutter mechanisms eliminates consumables and the subsequent carbon footprint associated with the production

1. GEW designs and manufactures arc and UV LED curing systems for printing, coating, and converting applications.



and transportation of those items," says Jennifer Heathcote, VP, business development, GEW (EC) Limited.

Financial benefits are achieved as well. UV LED is a lower energy system with light wavelengths concentrated in a much smaller range. "This system uses far less energy and generates far less heat than standard mercury arc UV, impacting ambient heating and cooling systems in the building as well," explains Griesenbeck.

UV LED curing systems reduce the total installed power and lower energy consumption during operation by up to 75 percent. "This is fantastic for a manufacturer's bottom line and directly impacts the sustainability efforts of the organization," says Heathcote.

COOLING SYSTEMS

One complication with UV and UV LED is the need to cool. Both air- and water-cooled technology are options.

"As electricity flows through UV LED technology, 30 to 40 percent of it is converted to wavelengths of UV energy, which radiates outward from the device in question. The balance is converted to thermal energy, which must be removed by either forced air or water circulation," explains Heathcote.

"Proper cooling stabilizes LED junction temperature at the optimal set point and is one of the most important factors for ensuring optimal system performance, UV output, and product lifetime. As a result of this, the choice of cooling and its design is not a trivial matter," continues Heathcote.

Neil Stickland, group marketing manager, Integration Technology Ltd., also suggests that sustainability of the cooling system depends on the environment. "Water cooling has obvious performance benefits but associated with additional costs, whereas air cooling while less efficient requires no chiller or water source. Removed heat could of course be used to help warm the room in cooler environments."

In addition, Heathcote believes that the cooling method is foremost dependent on the desired curing output of the UV system. "When greater levels of UV output are required, LEDs must be cooled with water circulation as this is most efficient and effective. When lower levels of UV output are needed, systems are cooled with either water or air. As long as the cooling system is properly engineered for the level of UV output and adequately maintained over time, either method is acceptable. The facility's ambient environment must also be considered as higher temperatures, greater relative humidity, and particulates in the air from other processes can compromise effectiveness of both cooling technologies."

When it comes to the air-cooled method, Hoge says the systems do not require external chillers so they are usually less expensive and require less maintenance compared with water-cooled systems. "Air-cooled systems have lower energy requirements and lower operational costs; water-cooled systems provide smaller form factors and have higher peak irradiance but require slightly more energy to run."

Heathcote agrees, noting that from a sustainability perspective, air cooling requires less electrical power and eliminates water conditioning, which consists of a precisely diluted solution of corrosion inhibitor and glycol.

Water-cooled systems also have advantages and limitations. Heathcote points out that a water-cooled system that emits greater UV output is more likely to drive faster machine speeds, increase capacity, improve cure, and allow for a greater range of UV-curable chemistry to be run on the line. "Water cooling is also better at maintaining lower LED junction temperatures, which improves device stability, performance, and product life."

Griesenbeck says water cooling is able to pull much more heat out of a system more efficiently compared to other options. "Air systems typically generate heat in the ambient environment, which further taxes any temperature regulation in the building. Since water is recirculated in a closed system it provides

2. Dr. Hönle AG is one of the leading suppliers of industrial UV technologies worldwide. Together with its subsidiaries, the company develops, produces, and sells UV LED units, UV LED equipment, inert UV dryers, UV lamps and UV bulbs, IR lamps, UV measuring technology, reflectors, solar simulation systems, and electronic power supplies.

the best solution for temperature stability and sustainability."

From a sustainability standpoint, Burger feels that supporters of air-cooled UV LED sources will argue that they use less energy than a water cooler. "However, air-cooled UV LEDs generally run on a lower level and are less intensive. Therefore it is quite possible that you will need more LED rows for a good curing result as you would need using a water-cooled version instead."

Kevin Joesel, industrial sales executive, Americas, Baldwin Technology's AMS Spectral UV division, believes there is actually little difference between the two types of cooling processes from a sustainability perspective. "The two factors that LED system designers need to consider is the output versus life compromise. There is a target temperature that designers need to keep the chips to ensure longer life."

He explains that systems with the highest power need to have higher cooling. The higher power the LED, the higher the cooling requirement, the more likely to use water as the cooling mechanism. "Water-cooled systems for UV LED are closed loop, which means the coolant is run through a chiller. This minimizes the environmental impact. What one has to remember is that LEDs cannot recover from a thermal event. Undercooling the chip you will significantly decrease the useful lifetime. They are not self repairing and the replacement of the chips can be costly and may cause unplanned line-down situations, which are also costly."

Where they do differ is that the UVA LEDs are driven much harder to generate higher output. "This means more energy is put into the LED, resulting in higher output of UV energy but also requires active cooling—air or water—to keep the chip in a temperature range that allows long life. The higher power the LED, the higher the cooling requirement," adds Joesel.

3. The XP Quatro Series of products are the newest high-speed UV LED curing systems from AMS Spectral UV - A Baldwin Technology Company.

Most systems that are used in industrial curing—like the converting and wood industries—require high energy and speeds and primarily use water-cooled systems. Laboratory and adhesive curing systems that have lower productivity requirements use air-cooled systems. "The good news is that the energy conversion—electrical to optical watts—continues to improve, which translates to lower active cooling requirements," continues Joesel.

GOING FORWARD

When it comes to any technology, there is usually room for improvement. This is certainly the case when discussing the relationship between sustainability and UV LED curing technologies. Advancements support efficient systems.

Heathcote stresses that sustainability will continue to improve with UV LED. "This is mostly the result of ongoing chemistry optimization that enables inks, coatings, and adhesives to react to a lower peak irradiance as well as better matching the requirements of the UV chemistry and line speed to the correct UV output during source selection and operation. Delivering too much UV LED energy is inefficient as whatever portion cannot be absorbed by the chemistry is immediately converted to heat upon contact with the ink, coating, or adhesive; web or part; in addition to the machine components."

She adds that operating UV LED curing systems at the optimal power level dictated by the line speed, chemistry, and lamp integration allows further reductions in electrical power and energy consumption to be realized. "Anything that allows the system to run at a lower UV output without comprising cure, line speed, and yields is a sustainability improvement. As UV LED curing process knowledge further improves and is actively implemented, the overall sustainability of UV LED curing and its use in manufacturing will continue to grow."

"Although UV LED systems currently consume low energy, I don't think they have reached their peak. Over time, they will likely become even more compact in size and the cooling methods will become even more efficient," predicts Hoge.

Burger also still expects increasing efficiency for UV LEDs. "This means that the power input/output relation is improving, which also helps to improve energy balances for UV LEDs."

She adds that cooling technologies are also continuously improving, especially when it comes to air cooling. "Here we are looking forward to higher intensities at the same level of power consumption" we are used to.

"Continuous improvement also comes in the form of prolonging the lifespan of a UV LED system, with a focus on when the LED lights fail or reach their life expectancy," notes Esteban Marin, senior sales manager, Heraeus Noblelight America LLC.

Joesel points out that with UV LEDs, sustainability is the equivalent of useful life. "UVA LED systems are very close to the maximum theoretical conversion. The next frontier is improving the far UV LEDs—UVC LEDs—conversion rate. As you move to lower UV wavelengths you have to use different base materials that are much more difficult and expensive to manufacture. The general example is that the energy output of 385 to 405 nanometer (nm) is roughly the same. When you move down to a 365 nm system, the energy output is about 80 percent of the 385 to 405 nm range. When you move to an even lower wavelength, such as 340 nm, the energy output is less than ten percent of the 395 nm system."

As you move to the sub-300 nm range, it is even less efficient and much shorter life. "Many companies will have warranties of about 20,000 hours for UVA systems and expect even longer useful life. When you compare that to UVC LEDs, the useful output lifetime is less than 2,000 hours. But, this is not too dissimilar to when UVA LEDs were first introduced around 2001 for industrial use. The efficiency and life was very low. As the UVC LED target market is for disinfection purposes, there is a large driver and corresponding investment in improving the UVC LED efficiencies and one can expect improvements in the future," explains Joesel.

"Systems are getting more efficient with new technology and production techniques, however since the LED arrays are already very efficient the improvements will likely be smaller than when they were going from mercury arc bulb technology to LED technology," notes Griesenbeck.

SUSTAINABILITY AS A DRIVER

Sustainability is an advantage of UV LED as well as driver for adoption.

"Currently, sustainability is a major driving factor of UV LED adoption," asserts Hoge. "We are noticing an increased adoption of UV LED curing due to rising energy costs, especially in Europe. As the cost of energy soars, printers and converters are adopting UV LED at a much faster pace."

In addition to rising energy costs, mercury bans in manufacturing processes are growing globally and also contributing to the increased adoption of UV LED curing. "All of the major brands are requiring environmentally sustainable processes from printers, converters, and other manufacturers. Now that LED has become a valid alternative to mercury UV, many large global companies are eliminating mercury from their factories all together," comments Hoge.

Joesel also sees sustainability as a driving factor for adoption. "Sustainability is now a primary consideration in conversion to UV LED on par with the direct financial justifications for more sophisticated customers."

"In my opinion, with the ever rising costs of energy and a focus on sustainability, a move to LED-based systems will continue," notes Griesenbeck.

"The single biggest sustainability factor driving UV LED adoption today and over the coming decade is the technology's ability to lower installed power, peak demand, and energy consumption during operation. This has an immediate and measurable benefit of reducing carbon footprint, which enables companies to more quickly, easily, and cost effectively meet Net Zero pledges. Transitioning to UV LED curing allows printers, coaters, and converters to simultaneously lower carbon footprint, reduce energy bills, remove stress from the electrical grid, and meet sustainability targets," notes Heathcote.

"The current situation of the European Union facing an energy constraint due to the conflict in Ukraine, or the challenging targets of the U.S. adopting a predominately electric vehicle fleet present sustainability roadblocks that more energy efficient technologies like UV LED could help solve," adds Marin.

SUSTAINABILITY MATTERS

Individuals and companies are searching for ways to cut energy, reduce pollution, and eliminate waste. UV LED technologies are able to check all of these boxes when it comes to the curing process of ink, coatings, or adhesives in industrial print applications.

From not containing mercury to consisting of few parts, UV LED systems offer a host of environmental benefits. Directly related to this is the great amount of energy saved when utilizing UV LED systems, which is a financial advantage as well. With these positives, it makes sense why many industry players see the future of curing moving toward UV LED. Driving this is demand from corporations and consumers for a more sustainable future. *IPM*

COMPANIES MENTIONED IPMdirect See page 16 for more information.

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150	Baldwin Technology's AMS Spectral UV	amsspectraluv.com
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