

UV LEDs – MARKET AND TECHNOLOGY TRENDS 2020

Market & Technology Report - October 2020

UVC LEDs are one solution to contain the COVID-19 pandemic, possibly making the market increase tenfold and reach \$2.5B in 2025.

WHAT'S NEW

- Analysis of COVID-19 pandemic's impact on the UV LED business
- Analysis of UVC LED market by disinfection application: water, air, and surface
- Analysis of UVC LED manufacturing cost

KEY FEATURES

- Analysis of main UV LED applications, with in-depth focus on UV curing and UV disinfection
- UV LED industry analysis, with strong focus on UVC LEDs
- UV LED performance and price analysis
- UV LED technology manufacturing analysis
- UV LED market forecast for 2008-2025, with in-depth analysis for UVC LEDs

REPORT OBJECTIVES

- Analysis COVID-19's impact on UV LED landscape including use-cases and market opportunity
- Review the global UV LED industry and provide insights into the modification of the value and supply chains following the penetration of this disruptive technology
- Understand the current status of UV LED manufacturing and analyze the performance and price roadmap
- Analyze the UV curing and UV disinfection industry, their different applications, and associated characteristics

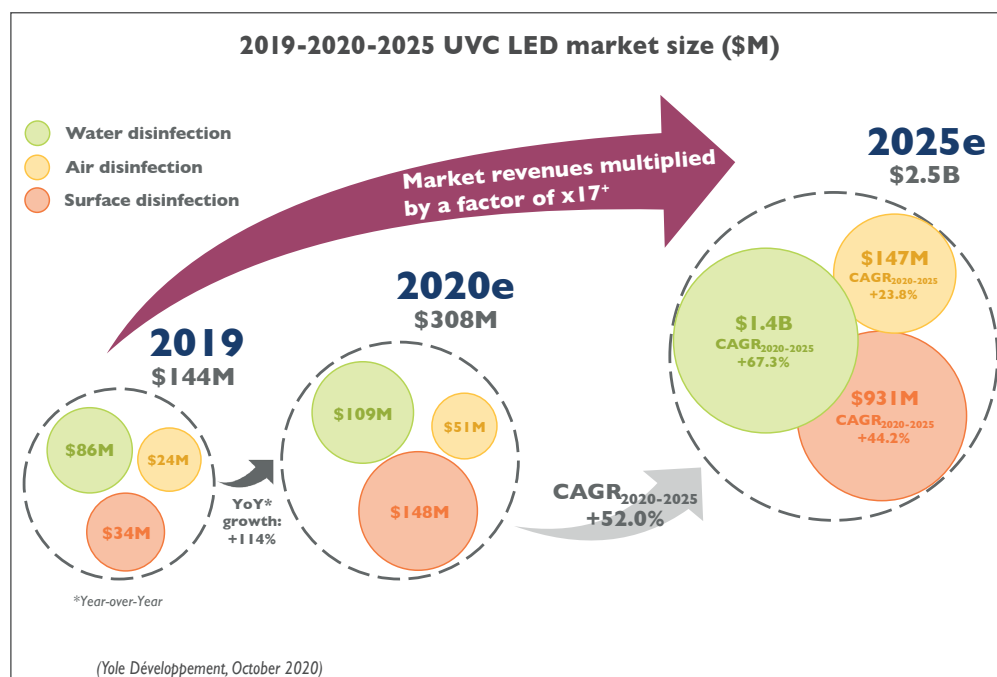
AFTER COVID-19 PANDEMIC INITIATES UVC LED GROWTH, MARKET COULD REACH \$2.5B IN 2025

Finally, we are here. After more than 10 years of waiting, in 2020, the UV LED market could ramp up and reach the billion-dollar mark very rapidly. There is good in everything bad, and the recent COVID-19 pandemic has created some perfect use-cases for the technology to spread across a rapidly-changing disinfection/purification market.

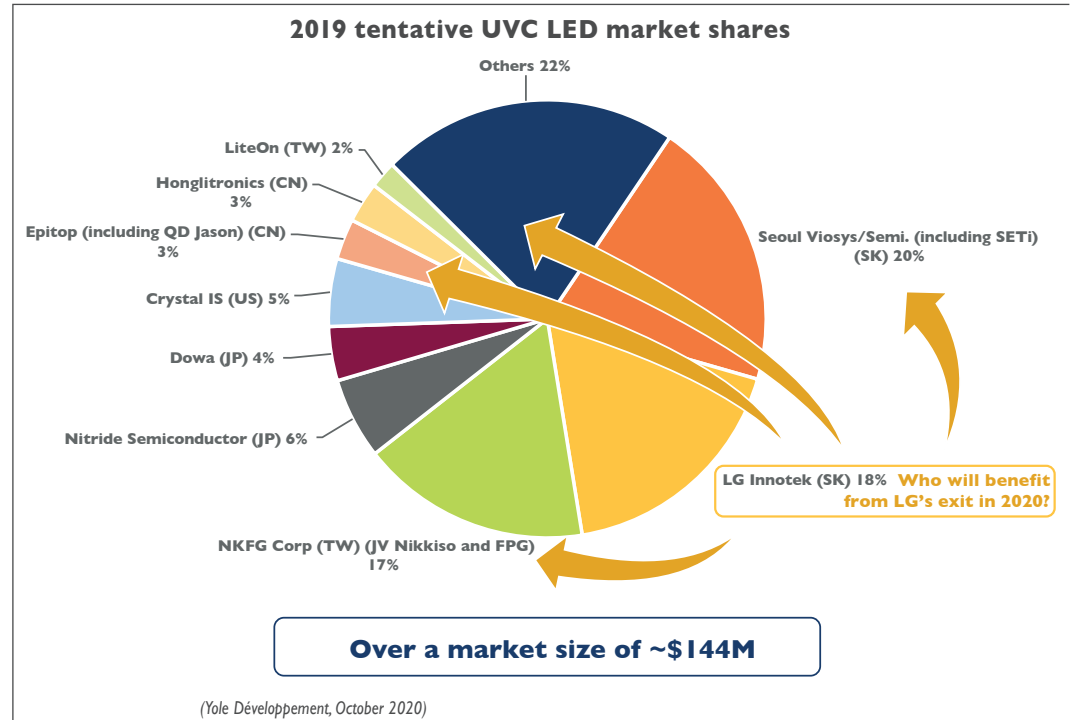
From being worth around \$20M in 2008, UV LEDs reached a first milestone in 2015 by attaining the \$100M market level. Such growth was mostly driven by UVA LEDs that were increasingly used in UV curing applications. But further growth was then restricted by the industry's overcapacity and strong price pressure following the massive entry of visible LED players starting from 2012. In this context, the attention of the industry was then focused on UVC LEDs that could act as a game-changer for disinfection/purification applications. But UVC LED technology is intrinsically different than for UVA LEDs. And whereas UVA LEDs' External Quantum Efficiency (EQE) has rapidly reached more than 50%, UVC LEDs' EQE is still below 10% in most commercial devices. Consequently, the technology was not considered mature by integrators and only early adopters started implementing it.

But that was before COVID-19 pandemic. SARS-COV-2, the virus that causes COVID-19, has one of the highest reproduction/transmissibility rates compared to all viruses that have emerged in our modern society. To reduce spread of the disease, many recommendations have been made by the World Health Organization and governments/authorities. But those best practices are mostly preventing infection from direct contacts. For infection based on close contacts or indirect ones through contaminated objects or surfaces, disinfection technologies are required to further reduce spread of the virus. In this field, UV lighting, which can deactivate bacteria and viruses through physical methods, has gained unprecedented attention.

The COVID-19 pandemic has created momentum for the UVC LED industry. From \$144M in 2019, the UVC LED market is expected to more than double in 2020 to reach \$308M. It could have been even bigger if production capacity could keep up with demand. With market growth now being triggered, we expect it to be worth more than \$2.5B in 2025, driven first by surface applications and then water ones.



THE UVC LED INDUSTRY IS IN THE STARTING BLOCKS



It's been more than 10 years that the industry has waited for this moment to happen, and all the players have worked hard to make it possible.

UVC LEDs are still much more expensive than traditional UV lamps, but manufacturers have got closer to the requirements of the early majority willing to use the technology. Indeed, from ~\$100/mW in 2015, UVC LED prices reached \$0.3-2/mW in 2019, which represents a real threshold for most potential large-volume integrators.

Such trends were made possible by the entry of several new entrants from the visible LED industry. Typically, LG Innotek and Seoul Semiconductor have been key companies in getting the UVC LED market ready to emerge. But their destinies will be different. LG Innotek started exiting the business before the COVID-19 pandemic, due to more than 10 years of consecutive losses of its visible LED division. Seoul Viosys has made an Initial Public Offering (IPO) in what can be considered as the best timing ever, when the pandemic started and UV lighting was drawing the attention of the entire world. The entry of several pure packager

and module players has also helped to accelerate technological development, and further reduce the gap between device manufacturers and integrators.

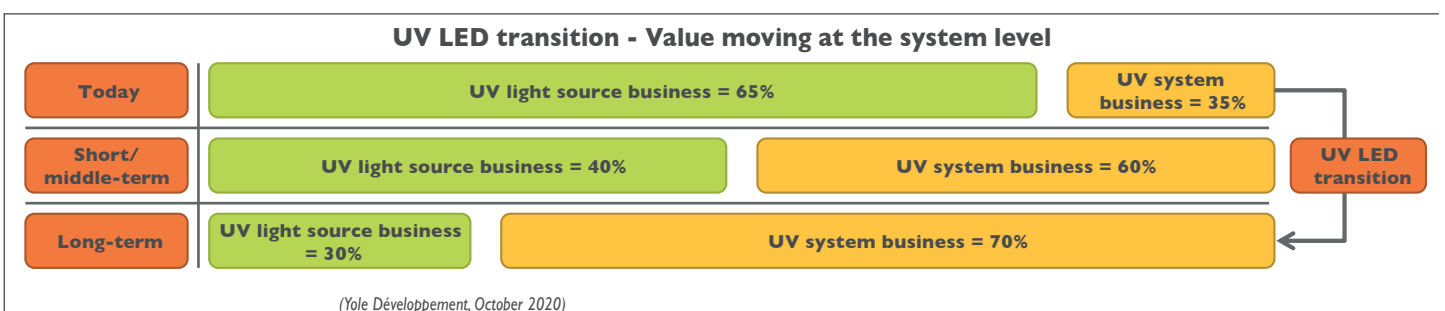
The overall industry was therefore ready for a boom in the UVC LED market – but what has happened has gone way beyond their expectations. The COVID-19 pandemic has created such a peak in demand that an overall shortage appeared across the entire UVC LED supply chain in 2020. And as such trends in demand are likely to last, the overall industry is now looking to increase manufacturing capacity very rapidly. As of Q3-2020, already more than 300M units of capacity have been announced to be installed in the short term.

Financial gain will further intensify the competition and it's likely that an industry experiencing such increase in demand will see big changes. We expect leaders like Seoul Viosys and NFKG to maintain their position in 2020 and 2021. But recent new entrants are close behind and will do their best to collect further market shares and catch orders left behind by LG Innotek.

UV LAMPS ARE NOT LEFT OUT - MORE BUSINESS FOR UV LEDS IN THE END

The traditional UV lamp industry has also a role to play as UVC LEDs are still less efficient and more

expensive than traditional UV lamps. UVC lamps also have the advantage of fixed specifications,



structural design, and circuits. These features allow manufacturers to easily produce systems according to specific requirements of the application, accelerating development time of products. Finally, there is still some lack of knowledge about UVC LEDs' disinfecting effectiveness, which will benefit incumbent technology.

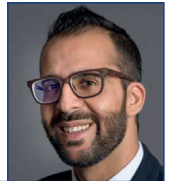
In this context, some traditional UV lamp manufacturers have already made a move to benefit from this momentum through increasing capacity of their production lines and/or development of new products. One concrete

example is market leader Signify, formerly Philips Lighting, which has a plan to multiply its production capacity eightfold very rapidly. Another trend is related to the development of far-UVC lamps that emit at wavelengths around 222nm to get rid of harmful effects of traditional UVC wavelengths.

At the end of the day, we expect such growth in the UV lamp business to come back to UV LED when the technology is on par with traditional UV lamps. Such a transition might then also further increase value at the system level.

COMPANIES CITED IN THE REPORT (non exhaustive list)

Advanced Ultraviolet Optoelectronics, Alpha One, American Opto Plus, Atomic Blue, Bioraytron, Bolb Inc., Brightek Optoelectronic, Bytech Electronics, ConvergeEver, CrayonNano, Crystal IS, Dowa, Edison Opto, Epigap Optotronic, EpiLEDs, Epistar, Epitop, Everlight, Genesis Photonic Inc., Guangzhou Hongli Optoelectronic, Harvatek, Hexatech, High Power Lighting, Hubei DUVTek, Inolux, ISON, Lattice Power, Ledtech, Lextar, Light Avenue, LiteOn, Lumens, Lumex, Luminus Devices, MarkTech Opto, Marubeni America Corp., NationStar, Nichia, Nikkiso, Nitride Semiconductors, Nitride Solutions, NKFG Corp, Opto Diode, Para Light Electronics, Photon Wave, Point Engineering, ProLight Opto, QD Jason Electric , QT Brightech, Sanan, Semicon Light, Seoul Viosys , SETi , Shenzhen Taoyuan Electron, Shenzhen Tianshengda Optoelectronic, Shenzhen UVET Electronics, Stanley Electric, Sunpu Opto, Toyoda Gosei, UV Photonics, UVON, Violumas , Vishay, Yes LED, Zhuhai Tianhui Electronic, and more.

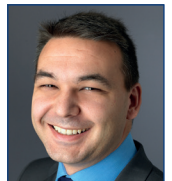


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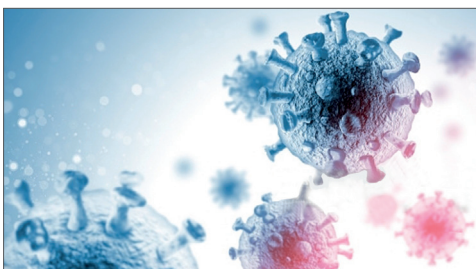
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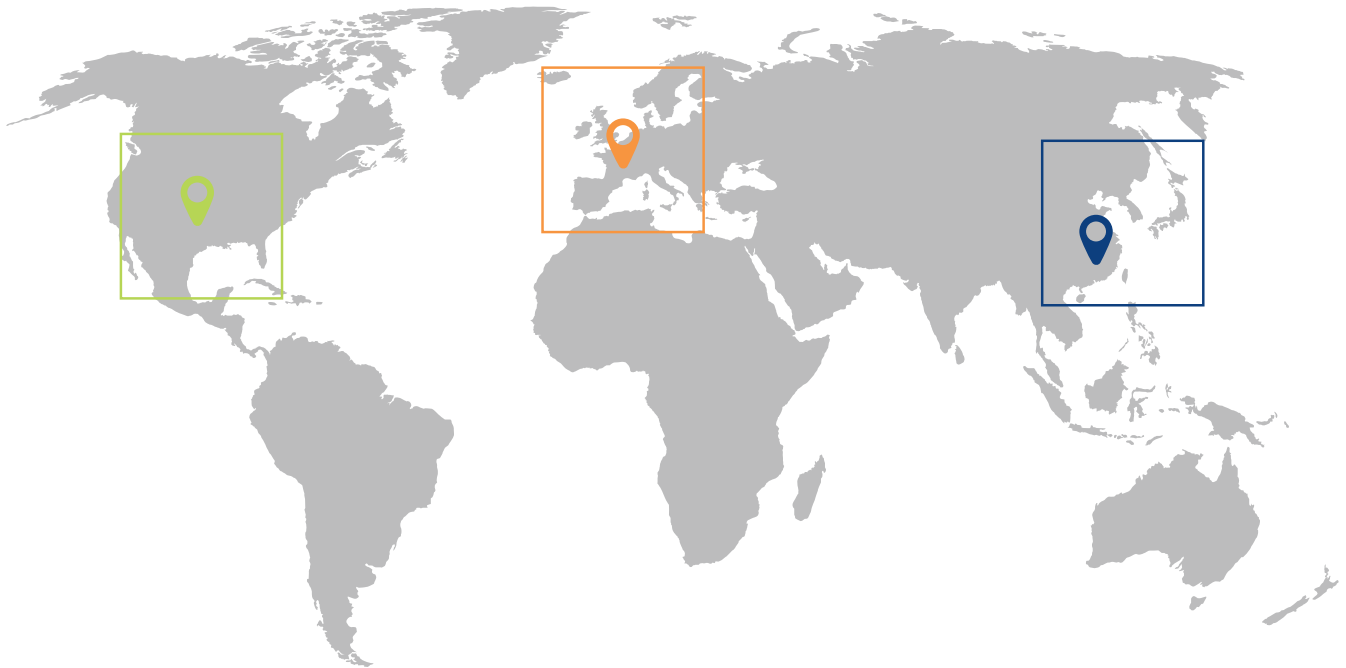
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- UV-C LEDs at the Time of COVID-19
- MicroLED Displays – Intellectual Property Status & Landscape 2020
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ABOUT YOLE DEVELOPPEMENT

Founded in 1998, Yole Développement (Yole) has grown to become a group of companies providing marketing, technology and strategy consulting, media and corporate finance services, reverse engineering and reverse costing services. With a strong focus on emerging applications using silicon and/or micro manufacturing, the Yole group of companies has expanded to include more than 120 collaborators worldwide covering MEMS and Image Sensors, Compound Semiconductors, RF Electronics, Solid-state Lighting, Displays, Software, Optoelectronics, Microfluidics & Medical, Advanced Packaging, Manufacturing, Power Electronics, Batteries & Energy Management and Memory.

The “More than Moore” market research, technology and strategy consulting company Yole Développement, along with its partners System Plus Consulting, PISEO and Blumorpho, supports industrial companies, investors and R&D organizations worldwide to help them understand markets and follow technology trends to grow their business.

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 - Within a reasonable time for Products ordered prior to their effective release. In this case, the Seller shall use its best endeavours to inform the Buyer of an indicative release date and the evolution of the work in progress.
- 2.2 The Seller shall by no means be responsible for any delay pursuant to Article 2.1 above, in particular in cases where a new event or access to new contradictory information would require the Seller analyst to dedicate extra time to compute or compare the data in order to enable the Seller to deliver a high quality Product.
- 2.3 The mailing of the Product will occur only upon payment by the Buyer, in accordance with the conditions contained in Article 3 above.

2.4. The mailing is operated through electronic means either by email via the sales department or automatically online via an email/password. The Buyer is responsible for ensuring that the Buyers platform has the required capacities and authorisations to receive the Product(s) emailed by the Seller. If the Product’s electronic delivery format is defective, the Seller undertakes to replace it at no charge to the Buyer provided that the Seller is informed of the defective formatting within 90 days from the date of the original download or receipt of the Product.

2.5 The person receiving the Products on behalf of the Buyer shall immediately verify the quality of the Products and their conformity with the order. Any claim for apparent defects or for non-conformity shall be sent in writing to the Seller within 8 days of receipt of the Products. For this purpose, the Buyer agrees to produce sufficient evidence of such defects.

2.6 No return of Products shall be accepted without prior written notification from the Buyer to the Seller, even in case of delayed delivery. Any Product returned to the Seller without the Buyer providing prior notification to the Seller as required under Article 2.5 above shall remain at the Buyer’s risk. In no event shall the Seller incur any liability for Products erroneously ordered by the Buyer, or for any request from the Buyer to replace a Product previously ordered by a different Product.

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3.1 Prices are given in the orders corresponding to each Product sold on a unit basis or corresponding to annual subscriptions. They are deemed to be inclusive of all taxes applicable in the country where the Seller is based (except for France where VAT will be added). The prices are re-evaluated from time to time by the Seller. The effective price is deemed to be the one applicable at the time of the order.

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HSBC, 1 place de la Bourse 69002 Lyon France
Bank code: 30056
Branch code: 00170
Account n°: 0170 200 1565 87
BIC or SWIFT code: CCFRFRPP
IBAN: FR76 3005 6001 7001 7020 0156 587

To secure the payments due to the Seller, the Seller reserves the right to request down payments from the Buyer. In such case, the need for a down payment will be mentioned on the corresponding order.

3.3 Payment is due by the Buyer to the Seller within 30 days from invoice date, except as otherwise specifically agreed in writing by the Buyer and the Seller. If the Buyer fails to pay at the due date and fails to request and obtain from the Seller a payment extension, the latter shall be entitled to invoice interest in arrears based on the annual rate Refi of the “BCE” + 7 points, in accordance with article L.441-6 of the French Commercial Code.

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4.1 The Buyer or any other individual or legal person acting on its behalf, being a business user buying the Products for its business activities, shall be solely responsible for the choice of the Products purchased as well as for the use and interpretations the Buyer makes of the documents it purchases, of the results the Buyer obtains, and of the advice and acts the Buyer bases thereon .

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- b) Any claim attributable to errors, omissions or other inaccuracies in a Product or interpretations thereof.

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4.4 Any Product that the Seller sells may, upon prior notice to the Buyer from time to time be modified by Seller or substituted with a similar Product meeting the needs of the Buyer. Such modification shall not lead to any liability of the Seller, provided that the Seller ensures the substituted Product is similar to the Product initially ordered.

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6.5 The Buyer shall define within its Company an identified user who shall serve as a contact person for the License purchased by the Buyer. This person will be the recipient of each new report. This person shall also be responsible on behalf of the Buyer, for compliance with all copyrights and other obligations relating to the protection of the Seller’s IP rights and general compliance with the terms of the License purchased by the Company. In the context of Bundle and Annual Subscriptions, the contact person shall decide within the Buyer which person(s) shall be entitled to receive the protected link that will allow the Buyer to access the Products.

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6.7 It is further acknowledged and agreed by the Buyer that any investor in the Buyer Company, any external consultant of the Buyer Company or any joint venture done with a third party in which the Buyer Company is involved , is not entitled to use a Product, without paying to the Seller the full price for a license to the required Product..

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8.1 All the provisions of these General Terms and Conditions of Sale are for the benefit of the Seller, but also for that of its licensors, resellers and agents. Each of them is entitled to assert and enforce these provisions against the Buyer.

Any notices under these Terms and Conditions shall be given in writing and shall be effective upon receipt by the other Party.

8.2 The Seller may, from time to time, update these General Terms and Conditions of Sale, and the Buyer, shall be deemed to have accepted the latest version of such General Terms and Conditions of Sale, once they have been duly communicated to the Buyer by the Seller.

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- 9.1 Any dispute arising out or linked to these General Terms and Conditions of Sale or to any Licenses or Products purchased in application thereof shall be submitted to the French Commercial Court of Lyon, which shall have exclusive jurisdiction upon such issues.
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