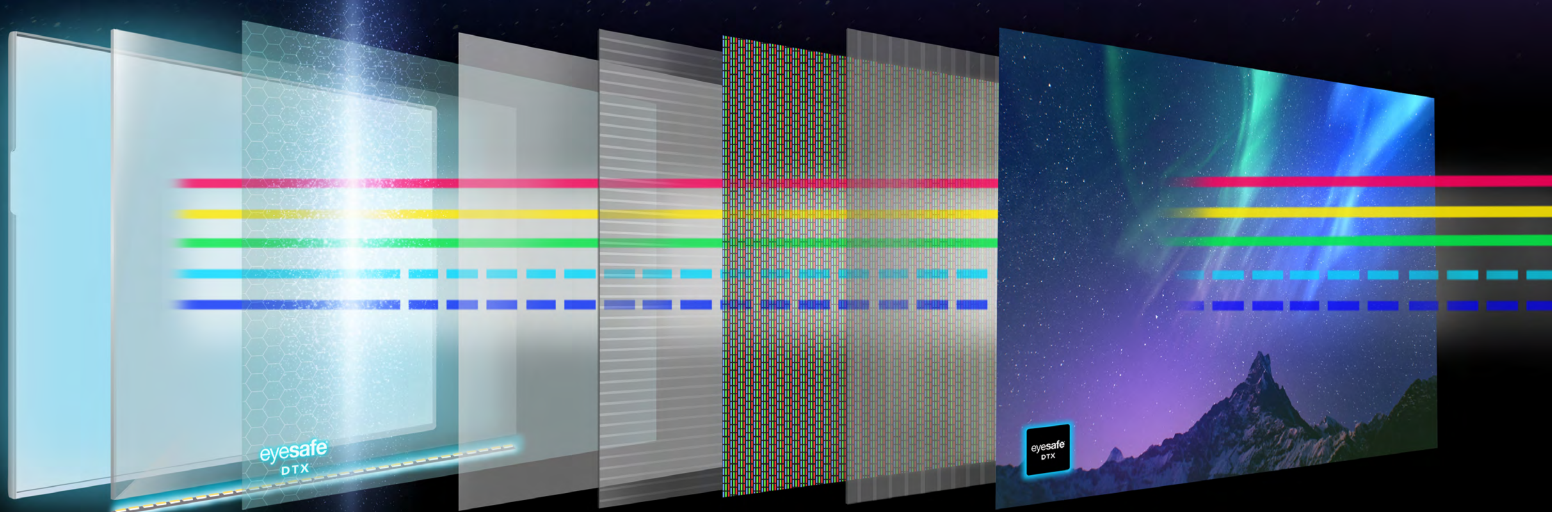
WHITE PAPER

Eyesafe® DTX

Utilizing High-Energy Blue Light to Improve Display Performance



eyesafe®

Eyesafe® DTX

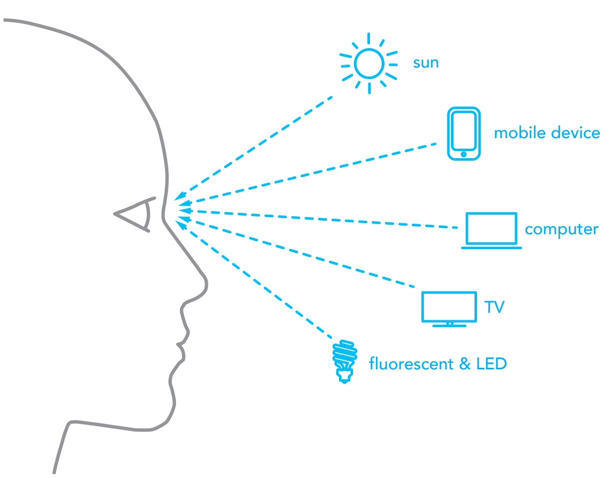
Utilizing High-Energy Blue Light to Improve Display Performance

INTRODUCTION

The next generation of high-energy blue light management is here. A technology that not only reduces blue light energy but utilizes it to improve display performance.

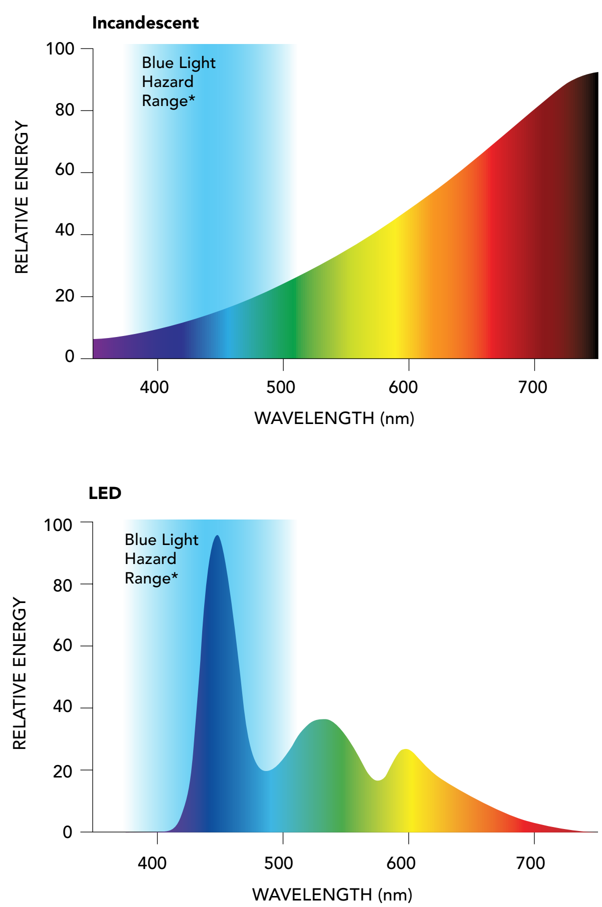
Eyesafe, a global leader in advanced blue light protection technology, solutions, and standards for the consumer electronics industry, is unveiling Eyesafe® DTX, an innovative and patented approach to reduce high-energy blue light in backlit displays, while improving color gamut, luminance and/or power efficiency. This white paper discusses the solution and how it offers significant benefits over conventional software and LED solutions, including performance benefits, ease of application and cost-effectiveness.

In today's ever-connected, always-on digital world, people use electronic devices for a variety of reasons, including work, schooling, and entertainment. While our largest source of blue light is the sun, our time spent on devices has been rising steadily for the last twenty years, now accounting for more than 13 hours a day.[1] The effects of excessive screen time for both children and adults are a topic of concern with the health community.



While people are exposed to both natural and artificial light throughout the day, we spend most of our waking hours in the presence of artificial lighting. LEDs, the most common light source used in computers, laptops, TVs, tablets, and mobile phones, have a different luminous profile compared to other light sources, such as sunlight, incandescent and florescent lighting. LEDs characteristically have a spike of high-energy blue light, while incandescent light does not exhibit the same spike (Figure 1).

Visit eyesafe.com/bluelight to learn more.



*Source: American National Standards Institute (ANSI) Z87.1 Table

Figure 1. Incandescent Light vs LED Light

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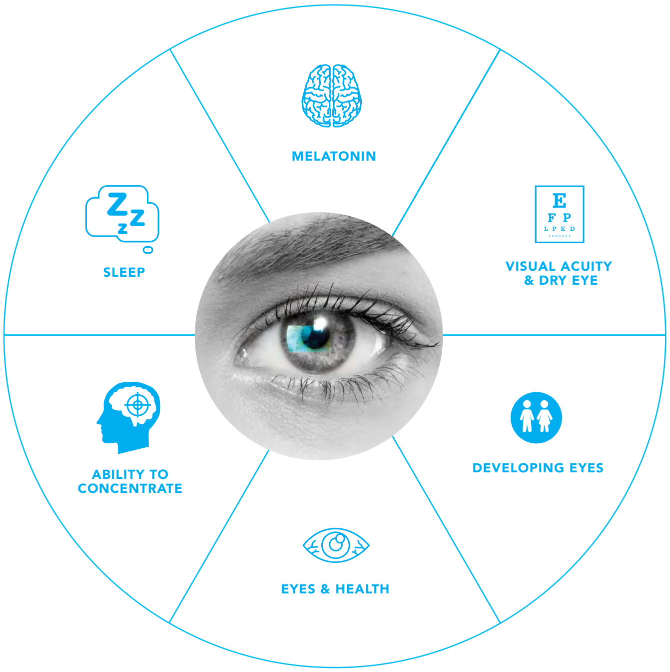
POTENTIAL BLUE LIGHT RISKS

Health Concerns are Growing

The increased use of digital displays is now being implicated as a health issue. The medical and scientific communities are increasingly concerned about both short-term and long-risks from digital screen usage and blue light exposure.[2,3] Studies have recognized the impact of device use on circadian rhythms and sleep patterns.[4,5] These disruptions are associated with multiple health problems.[6,7]

Phototoxicity is of particular concern and the eye is particularly susceptible to short wavelengths of light, such as blue light. Research has shown that exposure to high-energy blue light triggers the production of free radicals in ocular tissues. Lipofuscin, a biomarker for cellular aging and cumulative oxidative damage, linked to macular degeneration, is thought to be a product of various metabolic mechanisms, among them the blue light action on protein and molecules of the visual cycle: rhodopsin, *cis*-retinal and trans-retinal. One of the lipofuscin compounds, A2E, a phototoxic by-product formed from trans-retinal, absorbs within the blue light range leading to the production of more free radicals (ROS) and potential retinal damage.[8] Retinal damage, myopia, and age-related macular degeneration are of increasing concern to eyecare professionals because of the dramatic rise of these eye diseases globally over the last 20 years.[9]

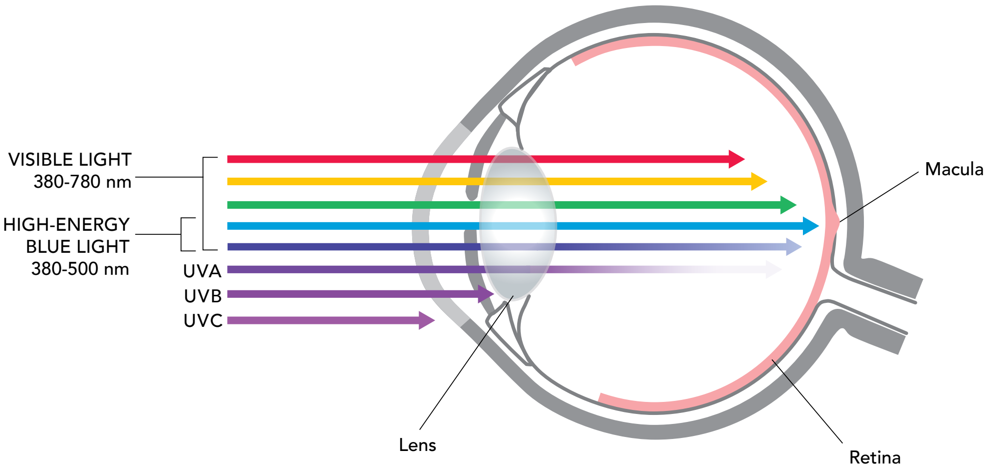
Visit eyesafe.com/research to learn more.



"Low blue light is quickly becoming the standard for monitors, notebooks, smartphones and soon, close-use virtual and augmented reality devices. Eyesafe DTX is a major step forward in the evolution of the display industry, making low blue light products a reality for more consumers around the world." – Richard Lindstrom, MD
World-recognized ophthalmologist and Eyesafe Vision Health Advisory Board member

BLUE LIGHT AND EYES

Visible light is transmitted to the retina from natural and artificial light sources, between the range of 380-780 nm. The cornea and lens of the adult human eye are effective at limiting UV rays from reaching the light-sensitive retina. HEV blue light is different, passing through the cornea and lens to the retina and macula.



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Health-Driven Product Design is Fueling Innovation

Addressing potential blue light risk from digital devices requires a closer look at the Blue Light Hazard Function Table, as all wavelengths within the blue light range don't represent equal risk. The Blue Light Hazard Table scales the blue light toxicity (levels between 0 and 1 by wavelength), as defined by the ANSI Z80.3-2018 standard. It peaks at 435 to 440 nanometers (nm) but extends at decreasing levels of toxicity through the blue range of the spectrum (Figure 2) from 380nm to 500nm and beyond.

Display makers have historically evaluated blue light hazard as a ratio of light energy originating within the 415-455nm range compared with the energy across the blue region (400-500nm), commonly referred to as the **Blue Light Ratio (BLR).** This was perhaps done to ease the design for the display manufacturers, simplifying it to a binary "toxic or not" scaling between that truncated range of 415nm to 455nm. The shortfall of assessing blue light risk as BLR becomes evident in looking at the blue light wavelengths that fall just outside 415-455nm, as shown in Figure 3.

For example, at 460nm, the toxicity factor is 0.80, indicating potential risk that is unaccounted for when relying on BLR as a primary metric of blue light exposure risk.

As research progresses, entities such as TÜV Rheinland, a global leader in independent inspection services and low blue light certification, are increasingly adopting the **Blue Light Toxicity Factor (BLTF)** as a benchmark for blue light risk, considering its use of the entire range of blue light hazard scaling factors.

The equation for BLTF is as follows:

$$BLTF = \frac{100}{683} \times \frac{\int_{380}^{780} L(\lambda) \times B(\lambda) \times d\lambda}{\int_{380}^{780} L(\lambda) \times \bar{Y}(\lambda) \times d\lambda}$$

In which:

- $d\lambda = 1$ nm
- $L(\lambda)$: spectral radiance in $\mu W \cdot cm^{-2} \cdot nm^{-1}$
- $B(\lambda)$: Blue Light Hazard Function
- $\bar{Y}(\lambda)$: CIE 1931 XYZ luminosity function
- 683 - maximum spectral luminous efficacy constant (683 lumens per Watt at 555 nm)

	EMISSIONS (nm)	BLUE LIGHT HAZARD FUNCTION*
UV	200-380	0
HIGH-ENERGY VISIBLE BLUE LIGHT	380	0.01
	385	0.01
	390	0.03
	395	0.05
	400	0.10
	405	0.20
	410	0.40
	415	0.80
	420	0.90
	425	0.95
	430	0.98
	435 Peak	1.00
	440 Peak	1.00
	445	0.97
	450	0.94
	455	0.90
	460	0.80
	465	0.70
	470	0.62
	475	0.55
	480	0.45
	485	0.40
	490	0.22
	495	0.16
	500	0.10

AREAS OF RESEARCH

- Ocular Surface Impacts
- Cataracts
- Retinal Cell Impact
- Potential for Age-related Macular Degeneration
- Circadian Rhythm Impact
- Melatonin Supression

*American National Standards Institute (ANSI) Z80.3 Table
International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines, most toxic portions of the blue spectrum

Figure 2. Blue light toxicity and its potential impact on eye health and overall human health.

	EMISSIONS (nm)	BLUE LIGHT HAZARD FUNCTION*	BLUE LIGHT RATIO (BLR)	BLUE LIGHT TOXICITY FACTOR (BLTF)
UV	200-380	0	0	0
HIGH-ENERGY VISIBLE BLUE LIGHT	380	0.01	0	0.01
	385	0.01	0	0.01
	390	0.03	0	0.03
	395	0.05	0	0.05
	400	0.10	0	0.10
	405	0.20	0	0.20
	410	0.40	0	0.40
	415	0.80	0	0.80
	420	0.90	1	0.90
	425	0.95	1	0.95
	430	0.98	1	0.98
	435 Peak	1.00	1	1.00
	440 Peak	1.00	1	1.00
	445	0.97	1	0.97
	450	0.94	1	0.94
	455	0.90	1	0.90
	460	0.80	0	0.80
	465	0.70	0	0.70
	470	0.62	0	0.62
	475	0.55	0	0.55
	480	0.45	0	0.45
	485	0.40	0	0.40
	490	0.22	0	0.22
	495	0.16	0	0.16
	500	0.10	0	0.10

*American National Standards Institute (ANSI) Z80.3 Table
International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines, most toxic portions of the blue spectrum

Figure 3. Blue light scaling measures of assessing toxicity risks to the retina. Toxicity factor is a more accurate metric for assessing blue light risk.

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Another way to view the measurement accuracy with BLTF versus BLR is shown in the curve in Figure 4. This shows a graphical description of both calculations. If you calculate the BLTF of each curve, one can see that BLR has an error of more than 40% in predicting the toxicity of a particular display. With today's technology, there is no reason to settle for this kind of error.

It is of particular interest The China Video Industry Association (CVIA) also adopted a ratio similar to BLTF in their 2017 standard for low blue light displays. In that standard, the emission from the display is weighted against the same blue light hazard scaling factors listed in Figure 3 and then divided by the total luminance from the display.[10]

"The introduction of Eyesafe DTX represents a pivotal moment for the global display industry. The ability to filter, capture and recycle blue light emissions to boost brightness and color performance – without changing the display stack design or supply chain – is a significant step forward." – Derek Harris, PhD, Vice President of Research and Development at Eyesafe

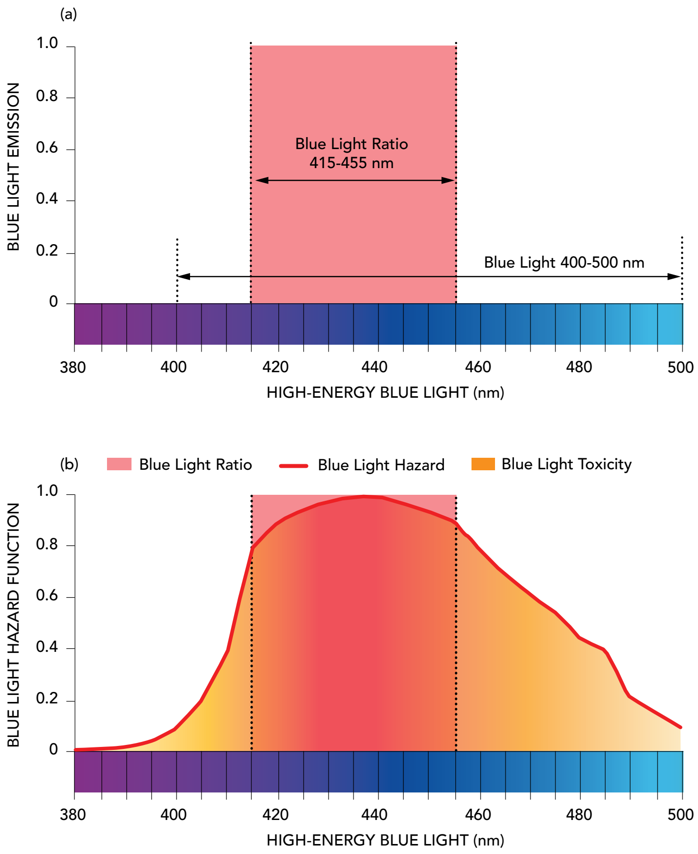

Figure 4. Differences in methods to characterize Blue Light Toxicity; BLR vs. BLTF.

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As Modern Lifestyles Change, our Technology Must Adapt

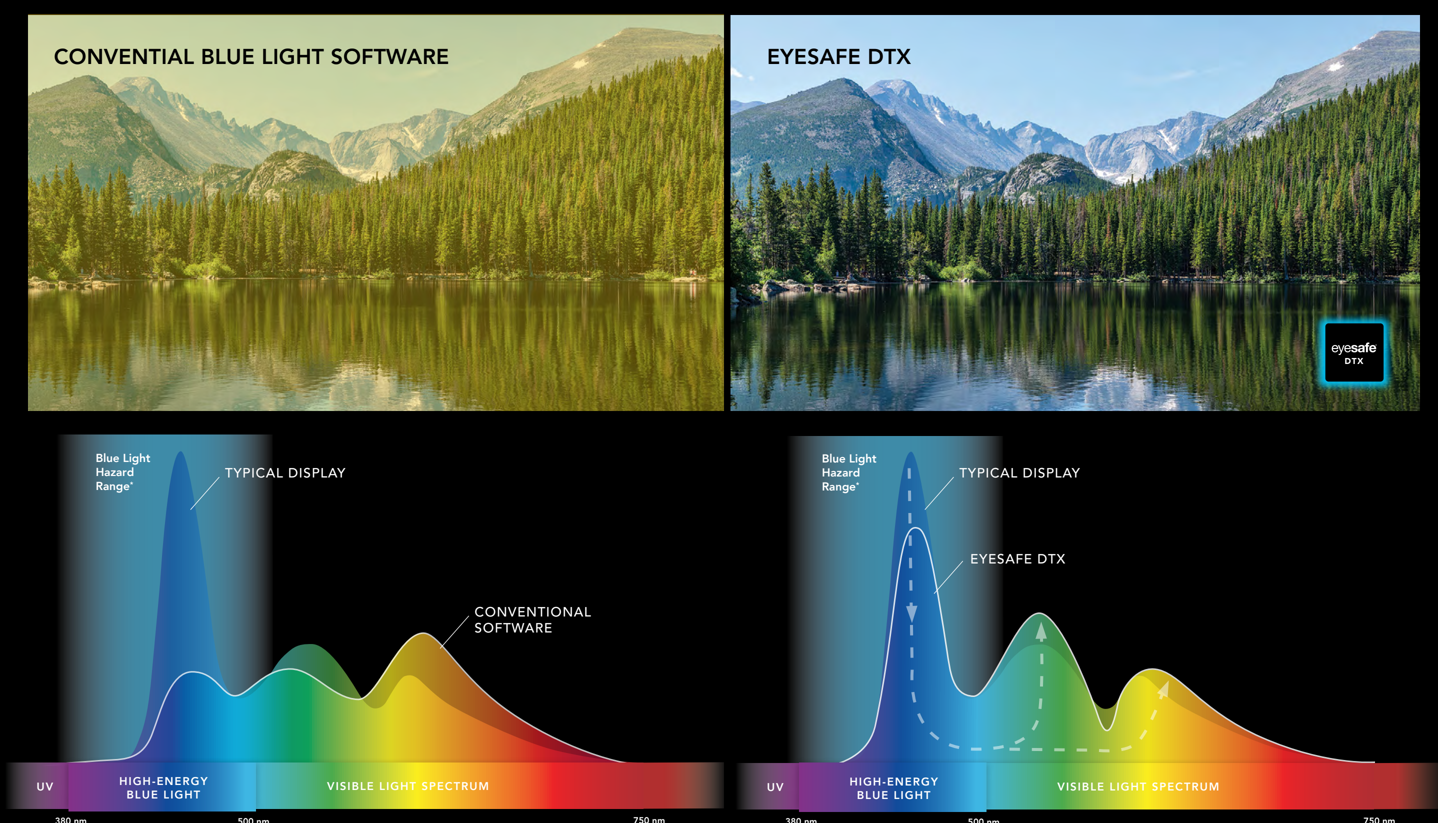
Electronics manufacturers and suppliers are quickly adapting their products to meet increasing consumer demand for low blue light displays. The conventional approach to reduce blue light includes software and hardware solutions, but they are not without their shortfalls.

Software solutions fundamentally work on the assumption that the blue value in RGB can be reduced by some arbitrary scaling amount. This brute force method causes a rapid deterioration in Correlated Color Temperature (CCT) and white point. Users are likely familiar with the yellowish coloration of the display with this feature enabled. As a result, users may shy away from this solution, especially for applications requiring better color.

Low blue light LEDs have a general design principle in shifting the peak blue wavelength higher, generally to 455nm and above. In addition to requiring a new LED phosphor design, other complexities are introduced with this approach, including changing and optimizing the color filter of the panel. At longer blue wavelengths, luminous efficacy, and therefore power efficiency, are lost due to a reduction in quantum yield of the phosphors. Next, due to color filter design, as blue wavelengths increase, the blue intensity at FOS increases. This causes a counter-intuitive increase in CCT and changed white point. Additionally, as the blue wavelengths move into the green emission area of the spectrum, the blue/green valley required for a good color gamut is compromised, resulting in less color gamut coverage overall. These are a few of the complexities that may lead to an expensive and time-consuming redesign of the panel to use more costly phosphors with different peak wavelengths, quantum efficiencies, and Full Width Half Maximums (FWHM) characteristics. This summary is by no means complete, but illustrates the difficulty and expense involved with this approach.

Perhaps the primary flaw, however, is that actual toxicity is not reduced significantly, according to a review of a sample of TÜV Rheinland Low Blue Light Hardware certified devices. In the vast majority of these devices, the blue peak wavelength is shifted minimally to move 50% of the energy outside of the window targeted by the BLR metric. Meaningful decreases in actual blue light hazard are minimal compared to the benefits of Eyesafe DTX technology presented here, typically less than a third.

Convential software solutions typically adjust high-energy blue light by shifting color and luminance, compared to Eyesafe DTX, which utilizes blue light toxicity to improve display performance and energy efficiency.



*Source: American National Standards Institute (ANSI) Z87.1 Table

The Eyesafe DTX Solution

Eyesafe DTX absorbs the blue light in the region of most concern to human eye health rather than shift it to wider wavelengths. It is effective at reducing blue light hazard and compensates for color change, luminance drop and CCT shift with color correction. Eyesafe DTX is a set of proprietary light management materials that are solution coated onto the diffuser sheet, and recycle toxic blue energy to other regions of the spectrum for optimal luminous efficacy. This approach combines the best of all worlds, resulting in:

1) Reduced blue light emissions
2) Increased or maintained color gamut coverage
3) Balanced CCT/white point
4) Increased or maintained luminance
5) Simplified, cost-effective drop-in technology

How Eyesafe DTX Works

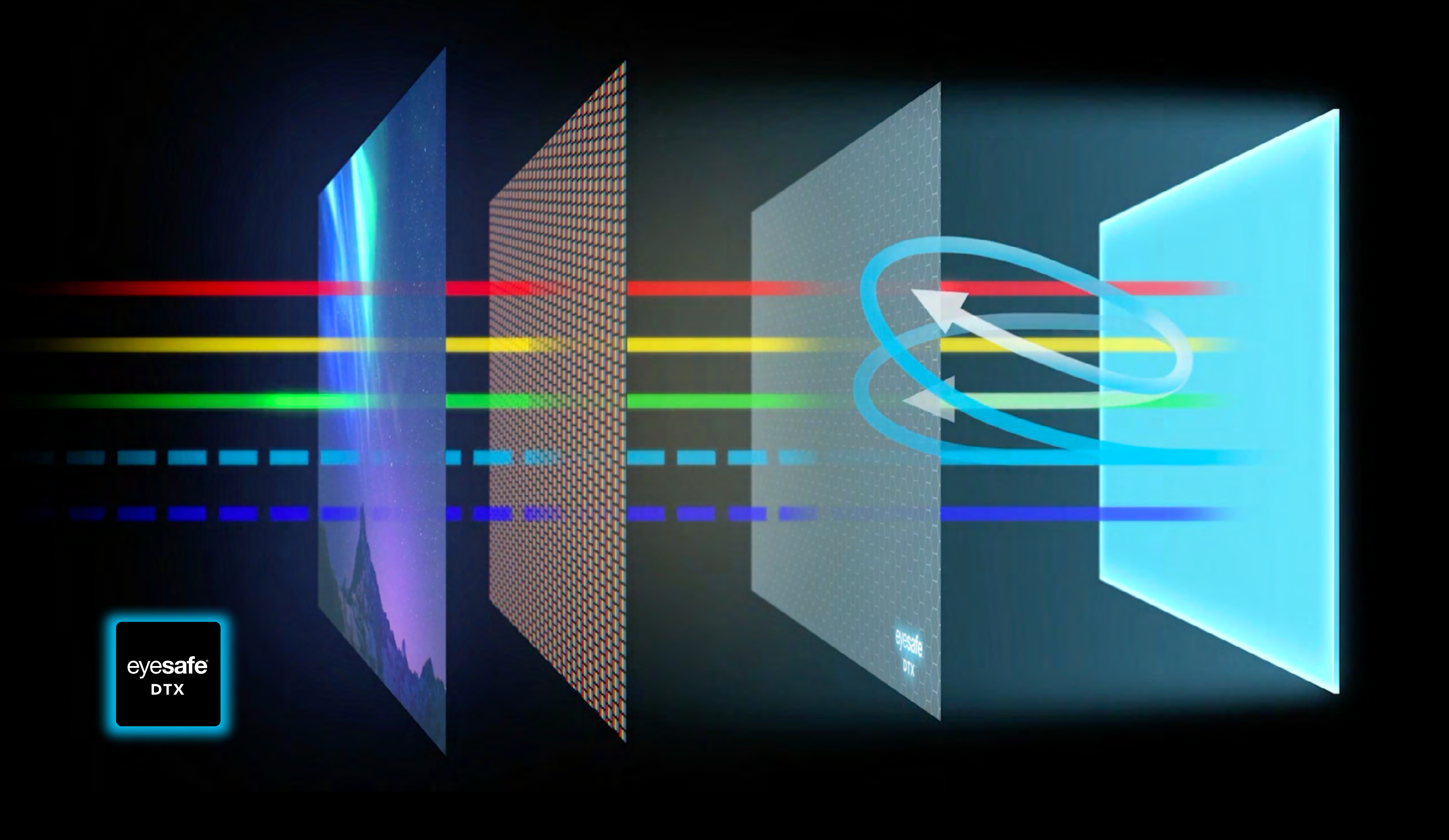
Eyesafe DTX technology uses proprietary materials applied to existing layers in the backlight unit to achieve significant reduction in BLTF vs. standard displays. The technology reduces high-energy blue light at the 435-440 nm peak harmful blue light region, with corresponding color adjustments at key locations of the spectrum to balance color. This optimizes the white point and improves color gamut and/or luminance.

Patented Eyesafe materials help address these areas:

- Blue light absorption, using a neutral density filter that reduces emissions within specific wavelengths
- Light management materials to balance color and improve panel performance
- Technology applied in LED encapsulants at the display backlight unit

Patents: Light Conversion US 10,955,697 and US 11,126,033; LED Encapsulate US 10,971,660, US and Foreign Patents Pending eyesafe.com/patents

Eyesafe DTX is a patented technology that absorbs and recycles blue light energy to the red and green parts of the color spectrum for improved luminance without color distortion.



Performance Advantage vs. Conventional LED Solutions

LED manufacturers continue to develop new technology to manage blue light. Historically, conventional low blue light LED solutions have required customers to trade-off luminance and/or color performance, but Eyesafe DTX is able to utilize high-energy blue light to improve display performance.

Figure 5 provides an example of performance advantages for a monitor with diffuser film with Eyesafe materials incorporated directly into that layer. All spectral measurements were taken with the same panel, driver electronics, and spectroradiometer. Panels were measured in native mode, with no scalar adjustments for color. Scalar-supplied voltages controlling LED current were left unmodified between measurements for the most accurate comparison of color and brightness. CIE 1931 coordinates were used.

As Figure 5 indicates, the monitor panel with Eyesafe DTX technology reduced BLTF significantly and increased sRGB and DCI-P3 gamut coverage and maintained luminance and white point.

A Tested Approach with Improved Stability

Eyesafe has partnered with leading display makers and Original Design Manufacturers (ODMs) to extensively test and refine its low blue light solution. The results show that it is widely applicable and has many benefits when compared to an approach that centers on swapping out or re-engineering the LED backlight.

Eyesafe DTX has specifically been subject to and passed the suite of environmental test requirements, including accelerated aging. Validation methods included one for accelerated aging. The test involved industrial monitor LED backlit LCD panels, where Eyesafe materials were incorporated into the diffuser material. These were tested and compared with control panels having standard diffusers. Tested panels exceeded validation requirements while operating at full brightness, high ambient thresholds (60°C / 90%RH for 1000 hours) and accelerated aging tests of 240 hours & 500 hours.

The Eyesafe materials within the tested panels showed improved stability compared with the control panels, with respect to change in luminance and color coordinates and with respect to blue light hazard.

Ease of Implementation

Eyesafe DTX is implemented directly within the backlight unit. It is incorporated directly within the current structure of the diffuser within the anti-blocking layer, resulting in no impact on the current structure of the display or z height dimensions.

Replacing the existing diffuser preserves the integrity of the display design and results in:

- Reduced costs and engineering time
- Reduced need for burn-in, stability testing
- No need to adjust LEDs and color filter
- All software controls remain effective

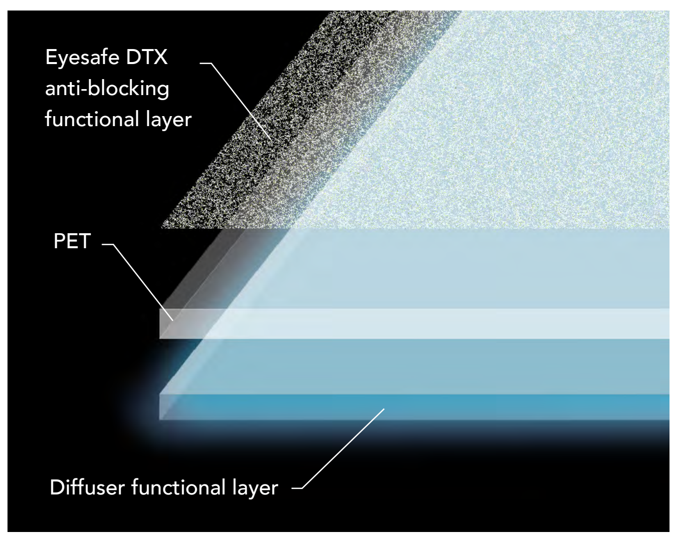


Figure 5. Performance advantages of Eyesafe DTX

Measurement	Blue Light Toxicity Factor	RPF®	sRGB (%)	DCI-P3 CIE 1931 (%)	Luminance (nits / % change)
Display as purchased	0.099	FAIL	98.2%	77.8%	275
Eyesafe DTX Diffuser	0.083	40	99.9%	80.6%	276 / +0.15%

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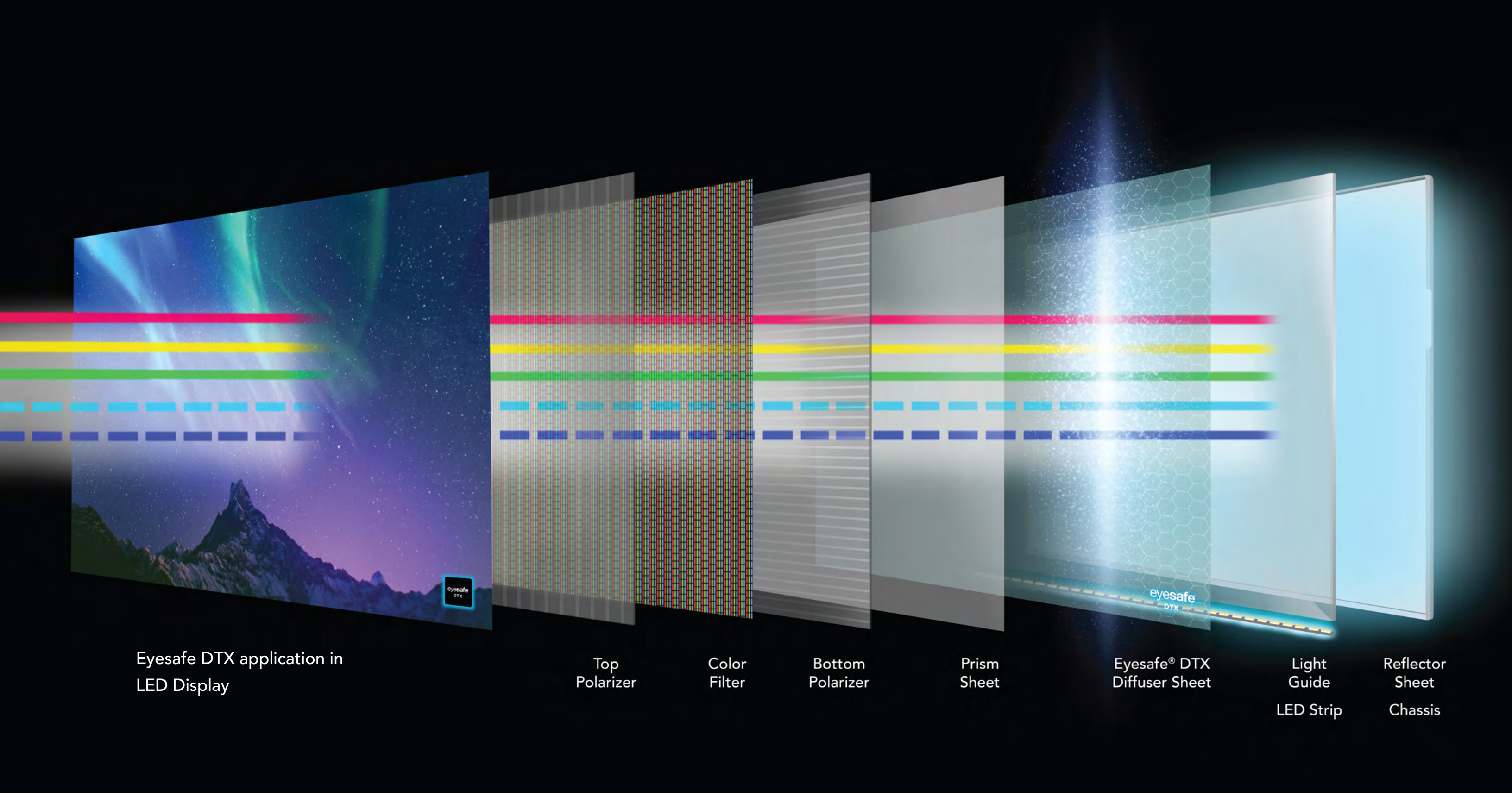
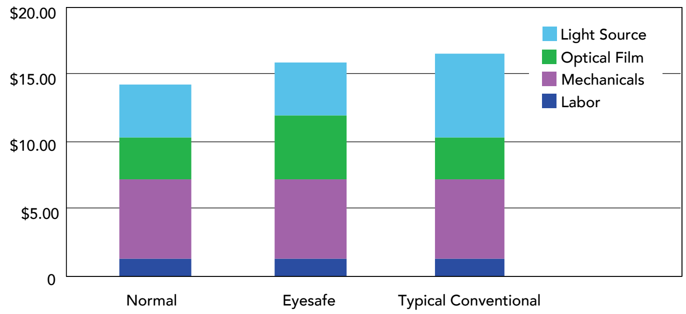


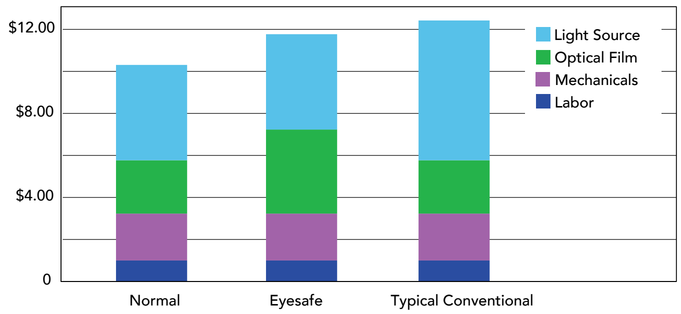
Cost Competitive

Compared to the conventional low blue light LED solution, a backlight unit incorporating Eyesafe DTX offers savings of up to 50%. The Eyesafe technology also avoids costs associated with changes to the color filter and additional design costs.

TYPICAL 23.8" FHD BLU FOR MONITOR



TYPICAL 15.6" FHD BLU FOR NOTEBOOK



Eyesafe DTX is suitable for a variety of applications, including TV, gaming monitors, commercial monitors, notebook PCs, mobile devices and more. The scalability, cost and ease of application makes it a practical blue light solution for low-to-high-volume applications and a wide range of product segments and price points.

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Eyesafe Certification and Radiance Protection Factor (RPF®)

Eyesafe DTX technology will enable displays to achieve stringent Eyesafe® Display Requirements for certification outlined in the chart below.

Visit eyesafe.com/standards to learn more.

During the certification process, displays will be tested and assigned an RPF. The RPF of a display indicates the level of blue light emissions at 200 nits and is calculated based on the BLTF of a display in comparison to the D65 illuminant BLTF. D65 is widely used in the lighting industry as a baseline because it roughly corresponds to the average midday light in Western Europe and Northern Europe (comprising both direct sunlight and the light diffused by a clear sky). D65 is not a real light source, but a simulation used to represent daylight at a given day and time.

RPF is calculated using a scaling factor that is based on the current technological limits of recent LCD and OLED technologies. The goal is to provide the end-user with a number (1-100) that reflects the blue light toxicity of the display, effectively simplifying the complex blue light toxicity formula used for measurement. Similar to how Sun Protection Factor (SPF) measures protection for the skin, the RPF scale measures blue light emissions and potential risk. The higher the number, the better — in essence, higher RPF numbers indicate a greater reduction of high-energy blue light in a display.

Visit eyesafe.com/rpf to learn more.

Conclusion

There is increasing evidence that high-energy blue light from artificial sources, like digital devices, has potential short-term and long-term risks.[11] BLTF provides the most comprehensive measure of potential blue light risk and scales directly to the Blue Light Hazard Function documented by several organizations, including ANSI.

Eyesafe DTX is an innovative technology for reducing BLTF, while also allowing for improved color gamut coverage and/or higher luminance. It's designed to be cost favorable for panel manufacturers to enable broader adoption of low blue light LED panels for OEMs. In addition to cost, Eyesafe DTX enables OEMs to achieve the industry-leading Eyesafe® Certification requirements. With certification, OEMs receive access to Eyesafe branding and comprehensive marketing support, including the newly introduced Radiance Protection Factor (RPF) identifier, to broaden product awareness and sales in-market.

Contact Eyesafe for more information.

EYESAFE DISPLAY REQUIREMENTS 2.0		
High-Energy Blue Light	Weighted blue light toxicity emissions based on ICNIRP Guidelines	Radiance Protection Factor (RPF) Pass/Fail of certification will be at RPF35. Measurement of blue light toxicity, based on research and optical testing. The RPF® scale is tested and verified by TÜV Rheinland.
Color Performance	Color Gamut Coverage %	For sRGB color mode: ≥95% of standard sRGB color space in CIE 1931; 1976 For Adobe RGB color mode: ≥90% of standard Adobe RGB color space in CIE 1931; 1976 For DCI-P3 color mode: ≥90% of standard DCI-P3 color space in CIE 1931; 1976 For NTSC color mode: ≥72% of standard NTSC color space in CIE 1931; 1976 * *For battery powered products NTSC color mode : ≥45% of standard NTSC color space in CIE 1931; 1976
	Color Temperature	5500-7000K

RADIANCE PROTECTION FACTOR (RPF)	
The metric for high-energy blue light reduction in digital displays. Just like SPF, higher numbers equal greater protection. Devices RPF35 and above meet Eyesafe Display Requirements 2.0, certified by TÜV Rheinland.	35 RPF®35 · 40 RPF®40 · 50 RPF®50 · 60 RPF®60 · 70 RPF®70 · 80 RPF®80 · 90 RPF®90

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AUTHORS

Derek Harris, PhD and VP R&D at Eyesafe received his PhD in Chemical Engineering from Georgia Institute of Technology. He has over 30 years spanning experience in liquid and vacuum deposited coating processes and formulation with the early parts of his career focused on electrochemistry.

Paul Broyles earned his engineering degree from The University of Texas at Austin. Paul served at HP for 26 years, in roles including Director, Engineering and Quality, Displays and Accessories. His history includes software and hardware engineering roles at IBM including groundbreaking work with the International Space Station.

Paul Herro, COO of Eyesafe, has led many successful first-of-kind market introductions of innovative technology solutions. Prior to Eyesafe, Paul was General Manager at Carestream Advanced Materials leading a new growth initiative developing optical films for the display industry.

Davis Lee, CSO of Eyesafe, formerly Senior Vice President at Dell Technologies where he served as the General Manager of the company's global display business. His nearly 25 years at LG Display culminated as SVP of Global Sales & Marketing, leading LG Display to be the #1 display company worldwide and launching OLED in mobile and automotive applications.

Elishaa Batdorf, Marketing Director of Eyesafe, has an MBA from the University of Minnesota Carlson School of Management. She has over 15 years of experience leading new product introductions and go-to-market strategy for CPG companies, including Mars Wrigley and P&G.

Richard Lindstrom, MD is the founder and attending surgeon at Minnesota Eye Consultants, Senior Lecturer and Foundation Trustee: University of Minnesota, and visiting professor at the UC Irvine Gavin Herbert Eye Institute. He has been at the forefront of ophthalmology's evolutionary changes throughout his career.

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FOR MORE INFORMATION

Researchers and eye care providers are increasingly concerned about the potential risks of high-energy blue light exposure. Eyesafe products are designed to limit blue light emissions based on the growing body of research.

Developed with Doctors

Developed with the Eyesafe Vision Health Advisory Board, a group of leading optometrists and ophthalmologists from across the globe. These distinguished eye doctors consult with Eyesafe to provide valuable insights that help drive research regarding the effects of blue light on the eyes and brain. They also help guide the development of Eyesafe technology and industry standards to limit blue light emitted by the displays of electronic devices and other sources. Eyesafe industry-leading low blue light certification is based on optical testing and research.

EYESAFE
VISION HEALTH
ADVISORY
BOARD

About Eyesafe

Eyesafe Inc. is the worldwide supplier of advanced blue light mitigating technology, solutions, and standards. With pioneering products and services, in collaboration with healthcare, Eyesafe is shaping the future of consumer electronics designed for human health. Eyesafe Standards, Eyesafe technology, and the associated intellectual property portfolio is developed by a world-class team of eye doctors, engineers, and scientists with decades of experience in electronics, display materials, light management, optometry, and ophthalmology. The Eyesafe brand is trusted by consumers and integrated in millions of digital devices from Dell, HP, Lenovo, ZAGG and others. Eyesafe was recently ranked #5 in the computer hardware category in the Inc. 5000 Fastest-Growing Private Companies in America. Learn more at eyesafe.com

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