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Bridging Light and Life™

Thrive Sunlight Spectrum - Human Centric Lighting

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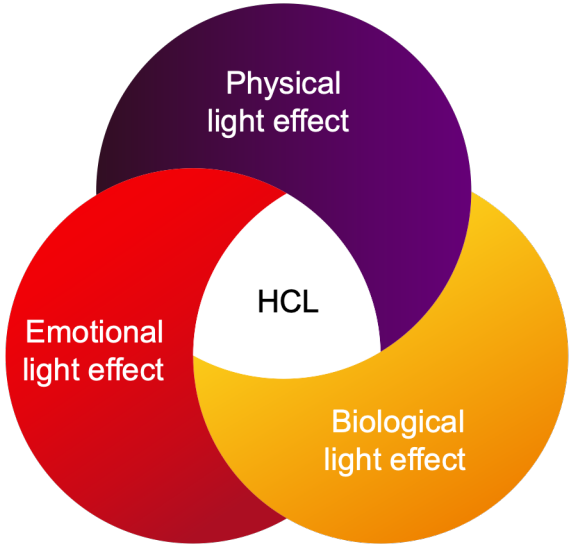
HUMANS

Have thrived for over 200,000 years under the sun's natural

DAY LIGHT

Human's Vision, Emotion and Health Thrives under Sunlight

- Human evolution is under the Sunlight.
- Human's Vision, Emotion and Health are adopted to the Sunlight spectrum.
- Humans spend an average of 87% of their time under artificial lights in enclosed buildings[1]
- Human Centric Lighting is expansion of general lighting from the illumination to the physical and emotional health and well-being.



[1] Source: N. E. Klepeis et al., "The National Human Activity Pattern Survey (NHAPS); a resource for assessing exposure to environmental pollutants," Journal of Exposure Analysis and Environmental Epidemiology, vol. 11, pp. 231-252, 2001.

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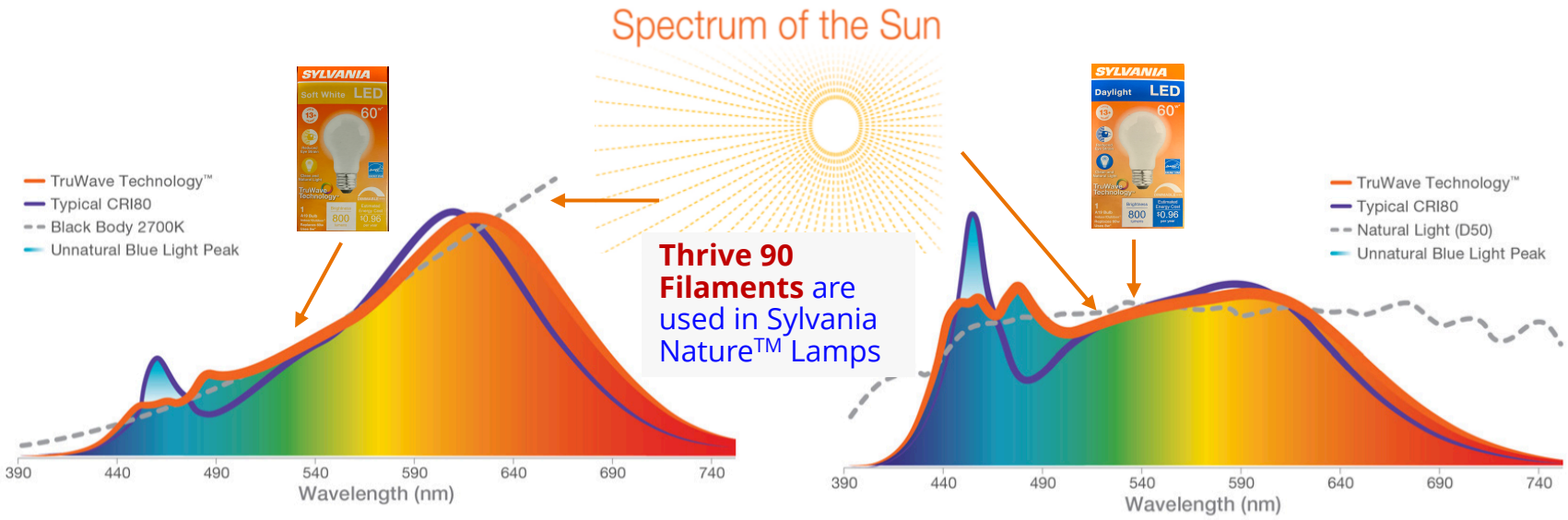
Enjoy Nature Sunlight Spectrum at Home

Bridgelux Thrive Full Spectrum LEDs

- delivers true Sunlight spectrum for human health and emotion wellbeing
- supports an improved sleep/wake cycle
- enhances your experience of true color as you see under Sunlight



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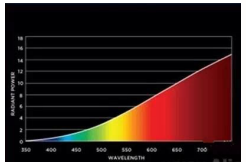
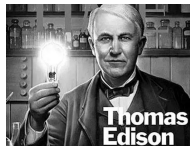
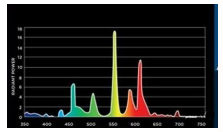
First Artificial Light with Energy Saving and Sunlight Spectrum for All Color Temperature



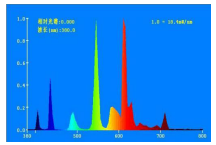


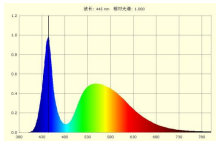
First Electrical Sun Spectrum Warm Light 1879

First Electrical Daylight 1939



PHILIPS 1980

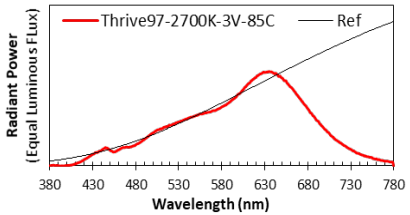


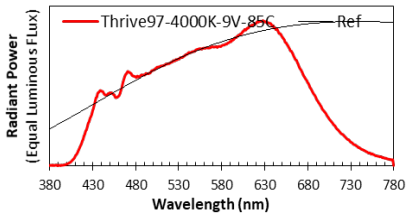


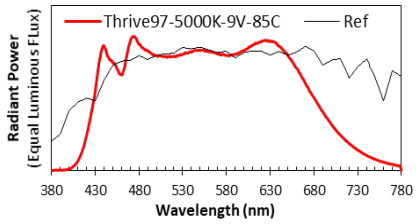
First Blue LED1994

- Fluorescent lamps and conventional LED lamps are not continuous color spectrum
- FL and CFL uses line emission phosphors
- Conventional LED uses narrow spike blue emission diode

First Electrical Sun Spectrum Daylight 2020







- Sunlight comprises a continuous color spectrum from UV, Visible to IR wavelength
- First artificial light is flame from wood and first Human (Edison) made electric light is tungsten filament lamp

- Sylvania Nature™ Lamps uses Bridgelux Thrive™ LED comprise broad blue diodes and enables a continuous color spectrum

[2] Source: J. Meister, "The #1 Office Perk? Natural Light", Harvard Business Review, September 3, 2018

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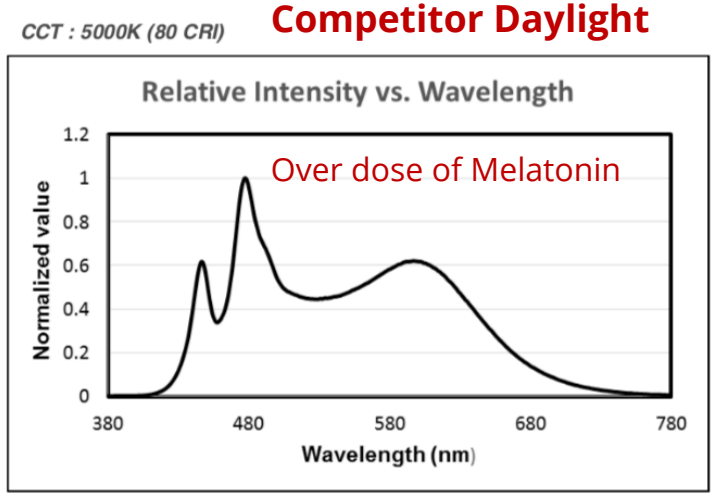
Thrive Sunlight Spectrum for Wellbeing

- Biological studies concluded that blue to cyan light is more responsible to human's emotion and circadian (biological rhythm clock) behavior. Any spectrum deviation from nature sunlight is not proper to human's wellness, and is either stimulate or depress human.

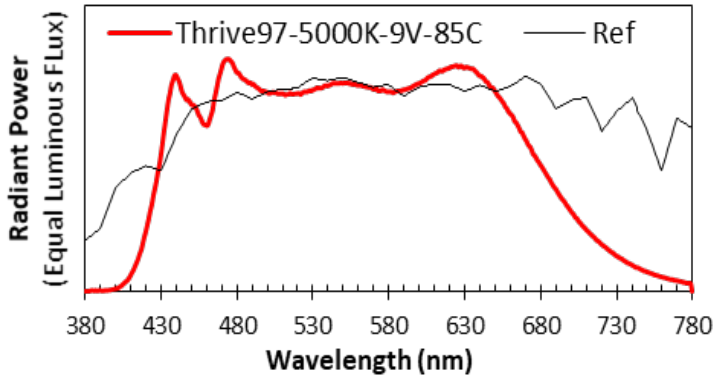
- Thrive LED in soft white lamps (2700K-3000K) mimic sunrise and sunset spectrum provide better sleep and wake cycle environment at home

- Thrive LED in daylight lamps (4000K-6500K) provides natural Sunlight working environment at home and office. This is the first time in history for an artificial daylight mimic the nature Daylight spectrum.

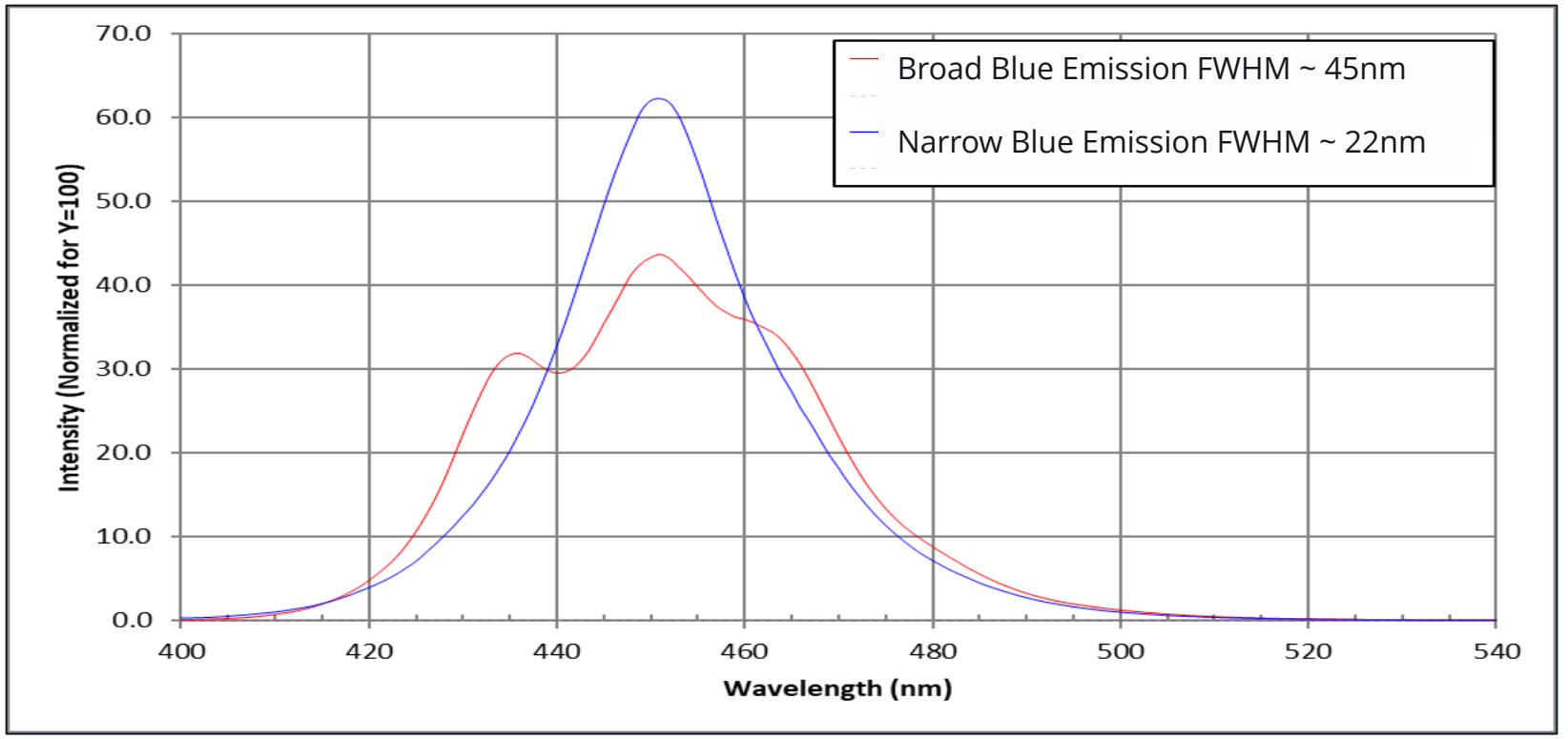
Competitor Daylight



Bridgelux Daylight



Thrive Blue Comparison – US Patents



Bridgelux Thrive Full Spectrum Products use multiple blue emission (broad band) chips as the excitation source in comparison to today's single narrow band emission blue chips.

US Patent

US10371325

- Full Spectrum LED comprising brodband blue emission with FWHM>30nm
- CRI R1-R15>90

US10685941

- Full Spectrum LED having R9<90 and the maximum intensity deviation in 430nm to 520nm wavelength range is less than 60% from blackbody curve or CIE Standard luminant D
- Full Spectrum LED having emission spectrum with Circadian Action Factor (CAF) within 5% of blackbody curve or CIE Standard luminant D

Thrive 97 SMD 2835 Specification

Product (BXEN)	CCT	CRI (typ.)	Typical Flux	Nominal Drive Current	Typical Voltage	Efficacy	Dimensions (mm)	Part Number
SMD 2835, 1W (13H-9) Download Data Sheet	2700K-6500K	98	98lm	100mA	9.1V	108 lm/W	3.55x2.82x0.70	BXEN-xxS-13H-9C-00-0-0
SMD 2835, 0.2W (11L-3C) Download Datasheet	2700K-6500K	98	24lm	60mA	2.9V	138 lm/W	3.55x2.82x0.70	BXEN-xxS-11L-3C-00-0-0
SMD 2835, 0.5W (11M-3C) Download Datasheet	2700K-6500K	98	56lm	150mA	2.9V	120 lm/W	3.55x2.82x0.70	BXEN-xxS-11M-3C-00-0-0

All measurements shown at 3000K Thrive, Tc=25C

Thrive 97 COB V4 to V18 Specification

Product (BXRE)	CCT	CRI (typ.)	SDCM	Typical Flux	Drive Current	Typical Voltage	Efficacy	LES	Part Number
V8D Thrive V8E Thrive Download Data Sheet	2700K-6500K	98	2, 3 and 4	677lm	350mA 175mA	17.2V 34.4V	105lm/W	8mm	BXRE-xxS0801-D-7x BXRE-xxS0801-E-7x
V10B Thrive V10C Thrive Download Data Sheet	2700K-6500K	98	2, 3 and 4	1077lm 1437lm	270mA 360mA	34.4V	116lm/W	10mm	BXRE-xxS1001-x-7x
V13C Thrive Download Data Sheet	2700K-6500K	98	2, 3 and 4	2520lm	630mA	34.4V	116lm/W	13mm	BXRE-xxS2001-x-7x
V18C Thrive Download Data Sheet	2700K-6500K	98	2, 3 and 4	4669lm	1170mA	34.4V	116lm/W	18mm	BXRE-xxS4001-x-7x

All measurements shown at 3000K Thrive, Tc=25C

Product (BXRH)	CCT	CRI (typ.)	SDCM	Typical Flux	Drive Current	Typical Voltage	Efficacy	LES	Part Number
V4 HD Thrive Download Data Sheet	2700K-6500K	98	2, 3 and 4	586lm	175mA	36.4V	92lm/W	5.2mm	BXRH-xxS0601-A-7x
V6 HD Thrive Download Data Sheet	2700K-6500K	98	2, 3 and 4	1223lm	350mA 700mA	36.4V 18.2V	96lm/W	7mm	BXRH-xxS1001-B-7x BXRH-xxS1001-G-7x

All measurements shown at 3000K Thrive, Tc=25C

Thrive Product Expansion

- **Thrive 97**
  - Goal: Closest match to natural light available over broadest wavelength range
  - Uses broad blue chip technology and special phosphor blend to fill in cyan gap and longer red with R1-R15>90
- **Thrive 93**
  - Goal: Increase Thrive to 90 CRI performance with R9>50
  - Uses broad blue chip technology and special phosphors to fill cyan gap
- **Thrive 85**
  - Goal: Increase Thrive to 80 CRI performance with R9>0
  - Uses broad blue chip technology and special phosphors to fill cyan gap
- **Broad blue**
  - Goal: Drop in replacement for normal 90 CRI in terms of efficacy and lumens with redistributed blue intensity over broad wavelength
  - Uses broad blue ship technology and 90 CRI phosphors

Technology	Thrive 97	Thrive 93	Thrive 85	Broad Blue 90
Broad blue chips	X	X	X	X
95 CRI Red Phosphor	X			
Cyan phosphors	X	X	X	
90 CRI Red phosphors		X		X
80 CRI Red phosphors			X	
Brightness	100%	108%	120%	110%

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Thrive Circadian Lighting

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Natural Lighting Is Not A Constant

Sunrise

Daylight

Twilight

Night

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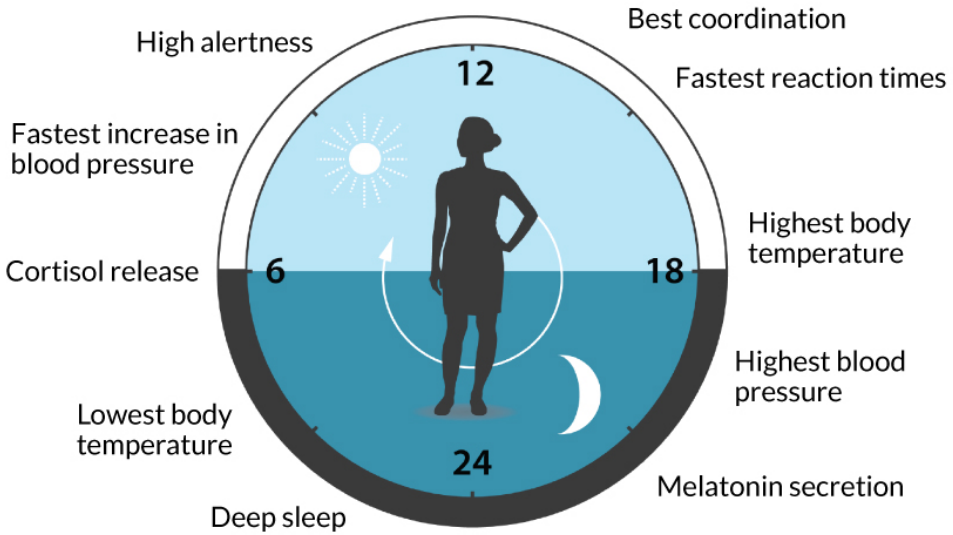
Circadian Lighting

- Natural lighting changes throughout the day in both intensity and spectra, varying by location, climate, and seasonality
- Human circadian rhythm responds to lightness and spectral composition, adjusting our biological clock
- Too much or too little exposure to certain types of light can then affect:
  - Alertness
  - Behavior
  - Sleep cycles
  - Personal health



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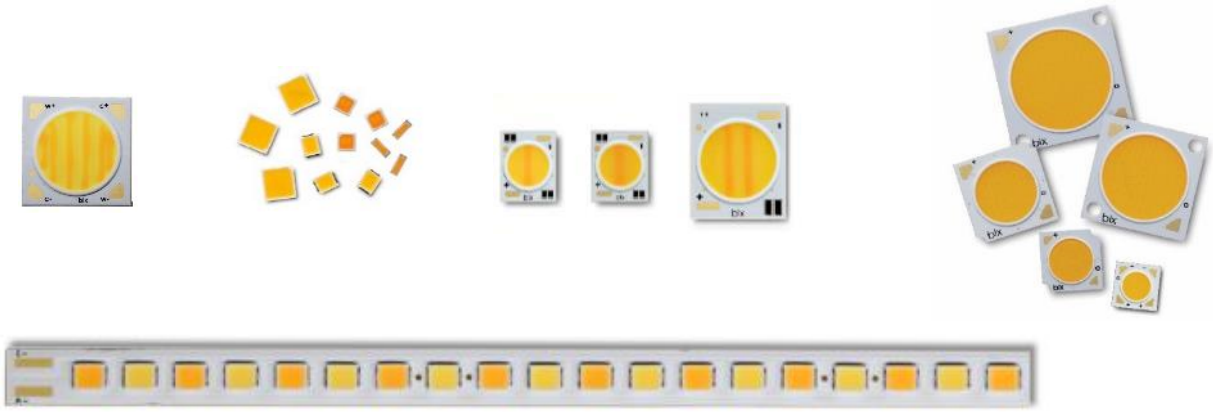
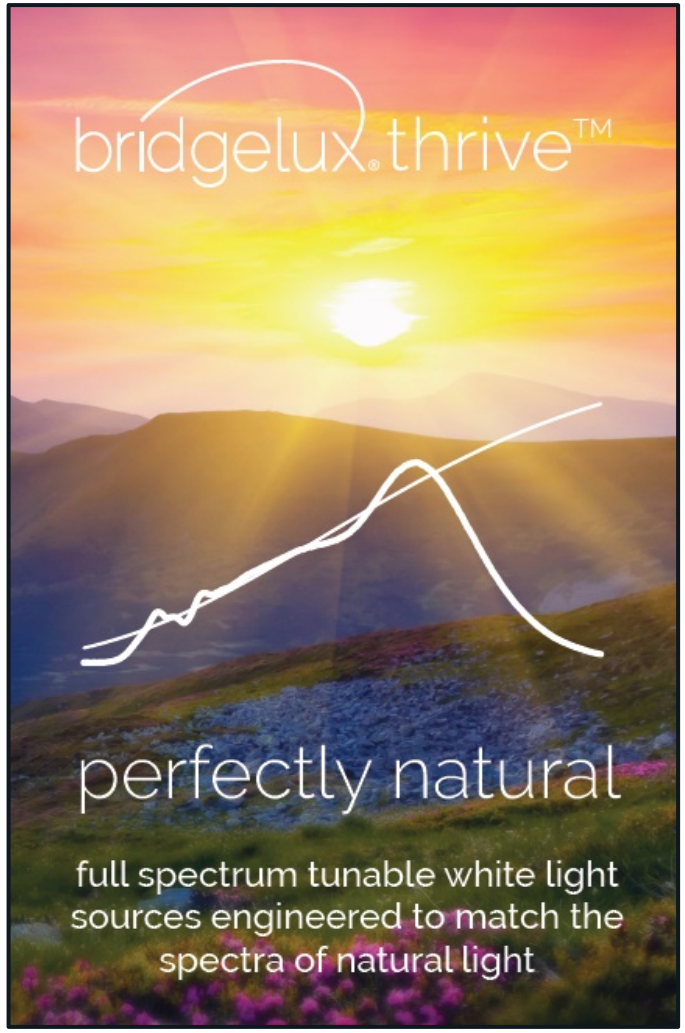
LEDs: Ideal Sources for Human Centric Lighting Innovation

- Spectral engineering enables light sources optimized to deliver spectra that closely match, or significantly deviate, from natural light sources
- Tunable white dynamic lighting systems can adjust automatically to track the spectra of the sunlight throughout the day, or allow us to personalize our environment to suit individual preferences





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Personalized Lighting

- Shaping our environment has been historically limited to adjusting brightness through dimming
- Tunable white HCL systems offer new possibilities to personalize lighting
- Benefits of smart, tunable, HCL systems include:
  - Education and Office
    - Mimic the natural phenomenon of sunlight variation with time of day to improve alertness and productivity[3]
  - Healthcare
    - Promote wakefulness and attention to detail for providers while mimicking natural sunlight variation in patient rooms to promote health and wellbeing and speed recovery
  - Office and Factory
    - Dynamically adjust lighting to improve sleep-wake cycles of factory workers[4]

[3] Source: S. Safranek and R. Davis, "Evaluating Tunable Lighting in Classrooms: Trial LED lighting systems in three classrooms in the Folsom Cordova Unified School District," U.S. DOE, PNNL report 27806, Sept. 2018

[4] Source: M. Figueiro et al., "Light, entrainment and alertness: A case study in offices," Lighting Research and Technology, 2019

Human Centric Lighting: Return On Investment

- Research shows that 90% of office business costs are related to employees[5,6]
  - Only 1% of office costs are related to energy, and 50% of that is spent on electricity
- Lighting solutions solely focused on increasing energy efficiency target only 0.5% of business costs
- HCL solutions that increase employee well-being and productivity target 90% of office business costs
  - While also addressing the strong desire for natural lighting as a desired workplace attribute to recruit and retain talent

[5] Source: M. Goh, "Try the 3-30-300 Rule as a Workplace Strategy," Electroindustry vol. 24 #4, pp. 4-5 July/August 2019
[6] Source: National Grid, "Managing Energy Costs in Office Buildings'"

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Bridgelux: Evolving with You

- We believe that human centric lighting is a right, not a privilege
- The intersection human centric and IoT connected lighting will deliver end user delight
- Bridgelux has the industry's largest portfolio of HCL light sources, drivers, and control ecosystems
- Partnering with our customers, Bridgelux is developing innovative system level solutions enabling simplicity, flexibility and consistency

https://www.bridgelux.com/todays-light/human-centric-lighting

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