

LUXEON SunPlus Solution for Horticulture

September 2018

From Greenhouses to Sustainable “Pinkhouses”

A photon is a terrible thing to waste in horticulture

The use of LEDs enables:



Up to 75% Energy Saving

Up to 35% of the cost of greenhouse tomatoes comes from heating and lighting



Up to 90% Water Savings

Less heat leads to less water evaporation, which helps to address the global water security crisis



Increase Growth Rate

Higher levels of red light increases tomato yield and the vitamin C content of mustard, spinach, and green onions



Example of benefits of LEDs for tomatoes

In the early 1980s, greenhouse tomatoes in the United States represented 1% of the retail market

Today they represent 80%, and it was the quality and taste of the tomato that drove that.

With LEDs to produce a tomato requires only 20% of the amount of water needed to grow in a field



Urban Farming

To meet future world's demand of food

By the year 2050

- World's population will reach **9.1 billion**
- **80%** of the earth's population will live in urban centers
- Food production must increase by **70%**

Solution: Indoor Vertical Farming



50K+ people can eat for an entire year from one vertical farm of 30 stories (2000Kcal diet)



No insecticides and no herbicides needed
Vegetables carry less bacteria, enabling a longer shelf life



Lower CO₂ by reducing transportation



Remove middle layers that affects the price of food



Safe to draughts and weather disasters



Home Farming

The grocery store of the future

Potential to provide up to 50% of city residents food

Increasing awareness on food quality and security

- Non-GMO
- Chemical-free
- Fresh produce, better taste
- No preservatives or ripening agents

Better for the environment

- No CO₂ emissions from transportation
- No pesticides that pollutes water
- Home farming stimulates Earth appreciation



Horticulture general applications

Consumer



Greenhouses



Inter-lighting

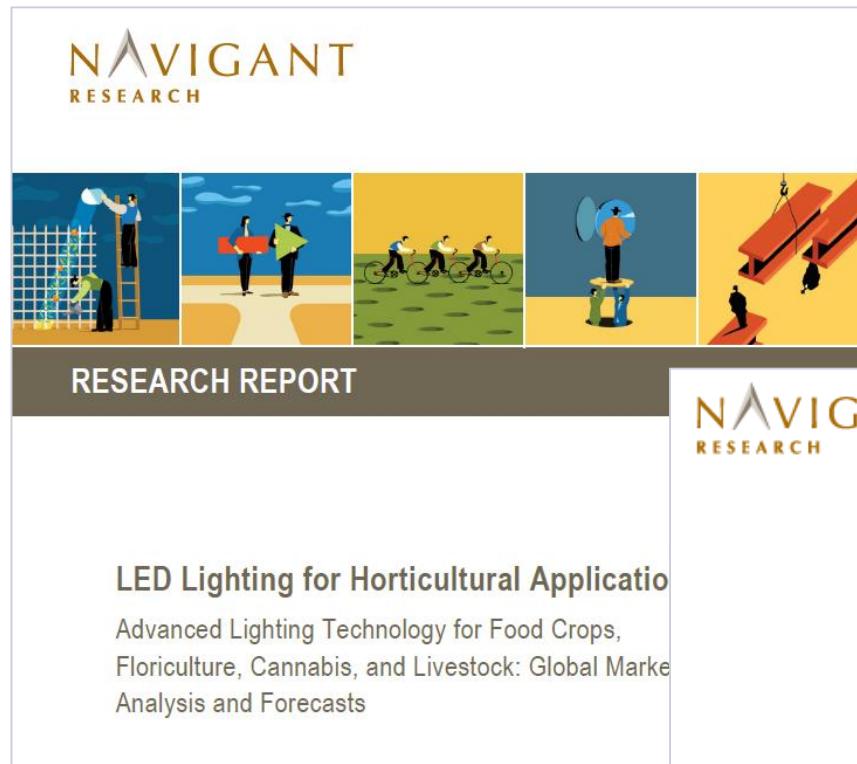


Multilayer cultivation



Why should you be interested in the Horticulture market?

Don't wait...capitalize now on the opportunity



83.3% Compound Annual Growth Rate (CAGR)

Astronomical growth

LED Lighting for Horticultural Applications

» Cannabis legalization: While cannabis makes up only a small share of the horticultural market, it is poised to grow quickly as more U.S. states and more countries legalize the production and sale of marijuana. Legalization is anticipated to be a double-edged sword for grow lighting, as the need to keep all plants hidden indoors will be eliminated. In many places, growing cannabis under the free light of the sun will be less expensive than using artificial lights, whether those lights are LEDs or otherwise. However, the significant increase that is forecast in the total cannabis crop, combined with the desire of many growers to tightly control growth conditions, is expected to lead to a rapid increase in the sales of lighting to this portion of the market.

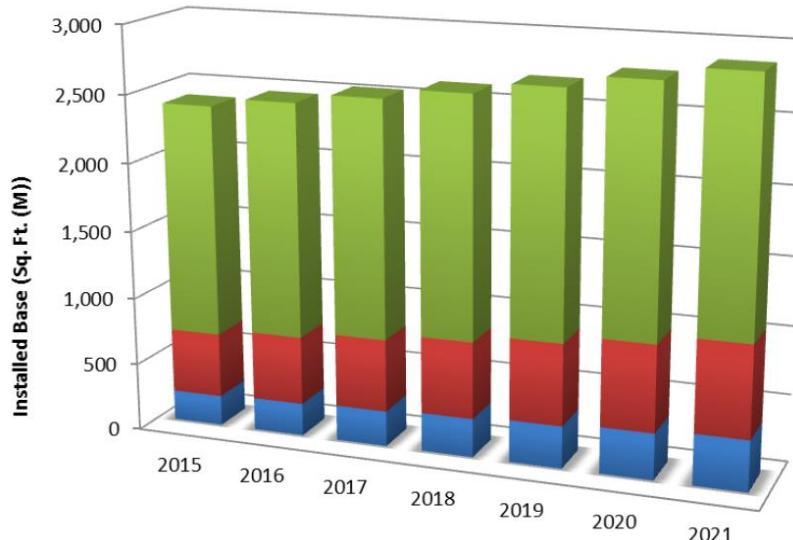
1.3 Forecast Highlights

LED horticultural luminaires are forecast to experience **astronomical growth** over the next 5 years as both the total amount of horticultural space and the adoption rate of LEDs increase rapidly. Unit sales are forecast to grow between 2015 and 2020 at a **83.3% compound annual growth rate (CAGR)**. Growth is anticipated to proceed more slowly through 2022, as many of the ripest renovation opportunities likely will have been taken, and overall growth in the number

Global Greenhouse Market Size

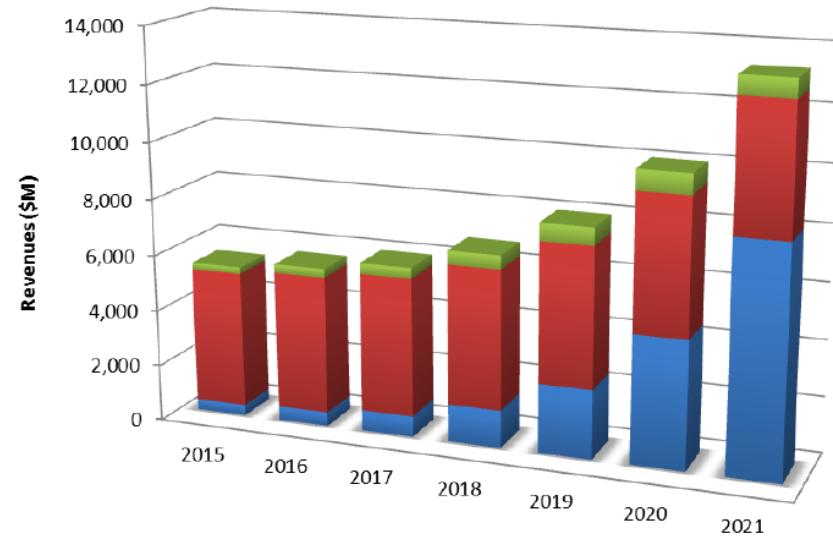
LED Fixture revenue estimated to grow from <\$500M in 2017 to >\$7B in 2021

Square feet of Illuminated Greenhouses



- Western Europe
- Rest of World
- North America

Greenhouse Lighting Revenue (Fixture Level)

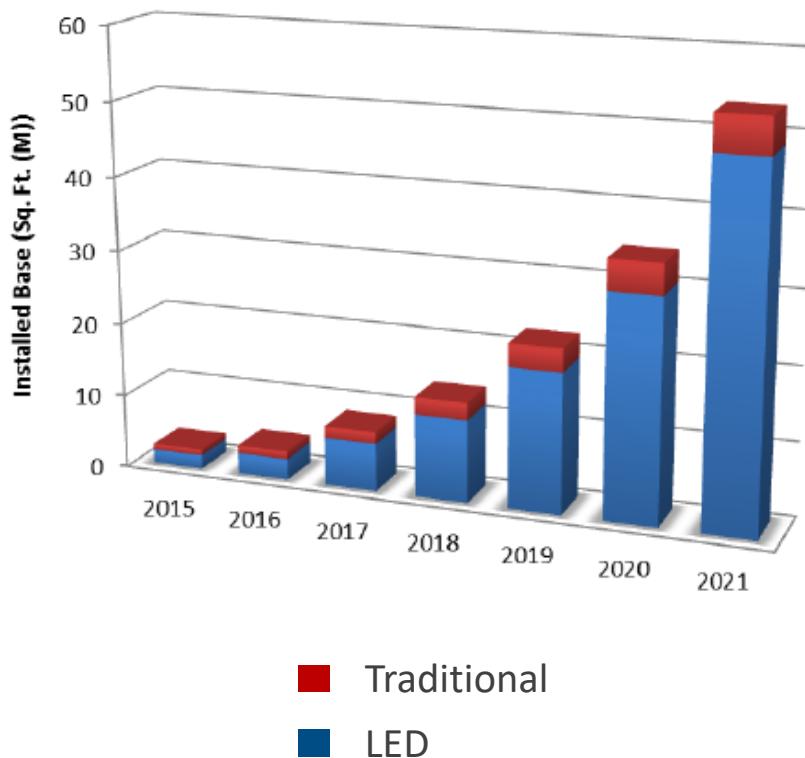


- Hybrid
- Traditional
- LED

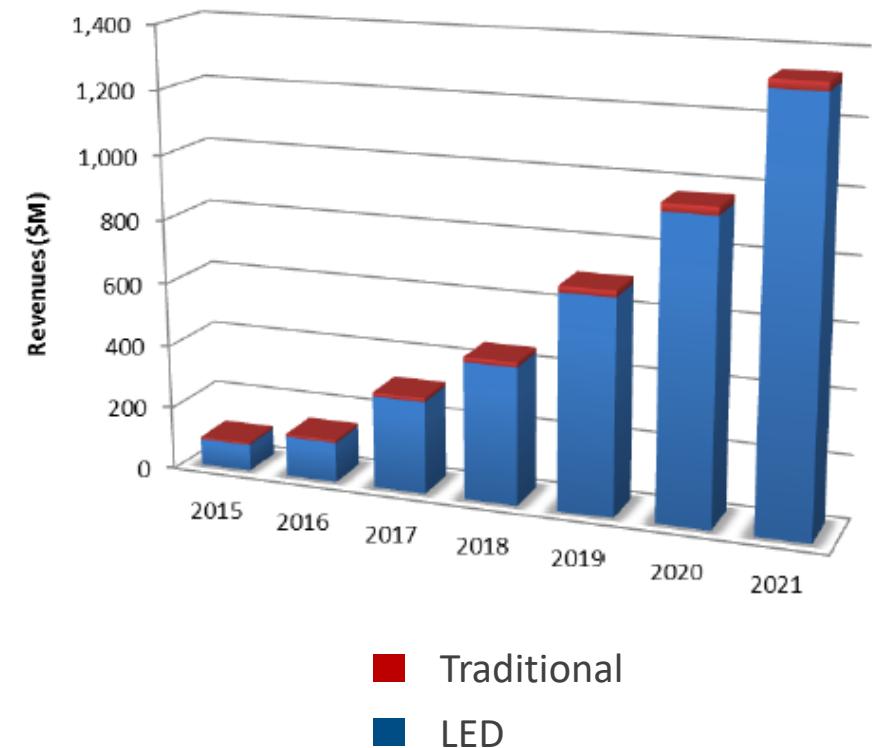
Global Vertical Farms Market Size

LED Fixture revenue estimated to grow from \$200M in 2017 to >\$1.2B in 2021

Square feet of Vertical Farms Growing Area



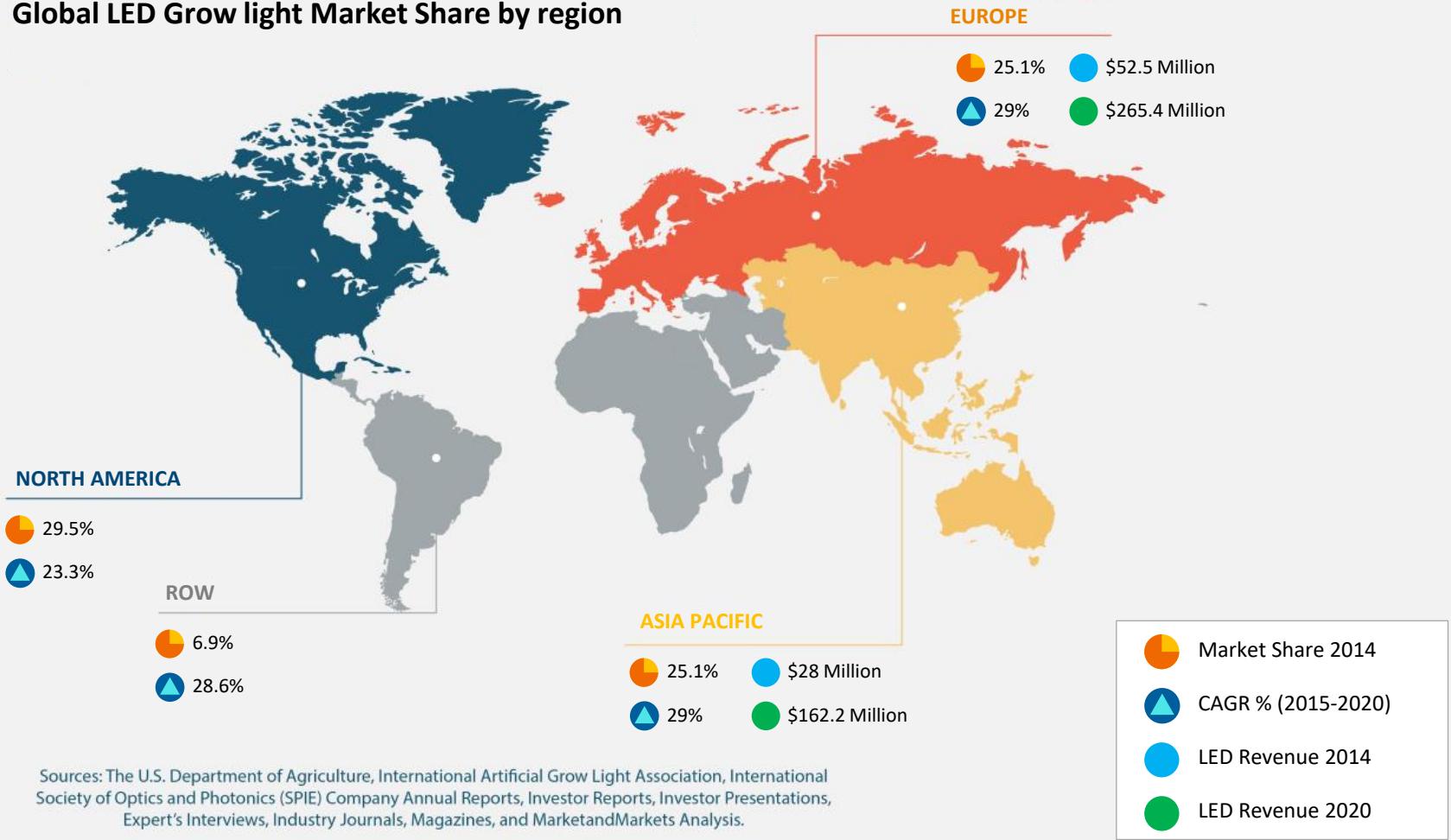
Vertical Farms Lighting Revenue (Fixture Level)



LED Market Size in Horticulture

Europe is and will be the biggest market followed by North America and Asia-Pacific

Global LED Grow light Market Share by region



Near to home....

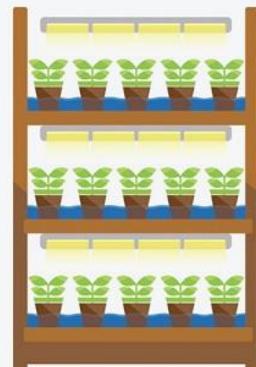
- <https://news.panasonic.com/global/stories/2015/44449.html>
- <https://www.youtube.com/watch?v=p-KJJWXmo6g>



Panasonic's farm-to-table benefits for consumers

FIRST LICENSED LOCAL INDOOR VEGETABLE FARM

- 1** Complies with AVA's stringent food safety standards
- 2** Optimum environment with controlled lighting, temperature, humidity & CO₂
- 3** Pesticide-free
- 4** HACCP certified



- 1** Optimised nutrient mix through R&D partnership with Singapore's Food Innovation & Resource Centre
- 2** Same day harvest & delivery to maintain freshness



ANTIOXIDANT MIX (VITAMIN C)

Benefit: Strengthens the immune system



Ingredients: Baby Spinach, Mizuna, White Radish, Yellow & Red Chard

NOURISH MIX (VITAMIN A)

Benefit: Enhances eye health



Ingredients: Oba, Rainbow Red Chard, Red Leafy Lettuce

VIBRANT MIX (MAGNESIUM & ZINC)

Benefit: Magnesium facilitates absorption & retention of calcium. Zinc is essential for growth



Ingredients: Green leafy lettuce, Mizuna, Red & White Radish











Glossary

Basic terms in the horticulture industry

PAR Region

- Photosynthetic Active Radiation is the bandwidth from 400nm to 700nm, which is the light plants primarily use
- Different plants require different wavelength combinations within the PAR region

PPF (Photosynthetic Photon Flux)

- Measured in $\mu\text{mol}/\text{s}$
- Total number of photons emitted per second in the PAR region
- But how much of that will reach your plant and at what distance?

$$\mu\text{mo l/s} = 10^6 \sum_{\lambda_i=400}^{700} \frac{P(\lambda_i) \cdot \lambda_i}{h \cdot c \cdot N_A}$$

P = Radiometric power
 λ_i = Wavelength
h = Planck constant
c = Speed of light
 N_A = Avogadro constant

PPFD (Photosynthetic Photon Flux Density)

- Measured in $\mu\text{mol}/\text{m}^2\text{s}$
- Represents the number of photons that reaches the plant within the PAR region over a given area
- It declines exponentially as the distance between the light source and the plant surface increases

DLI (Daily Lighting Integral)

- Plants need a minimum amount of light per day to meet their basic biological needs, it varies based on species
- For flowering and fruiting high levels of light can show significant increases in both the quality and quantity
- DLI = PPFD ($\mu\text{mol}/\text{m}^2\text{s}$) x 3,600 (s/hr) x photoperiod (hrs/day)**

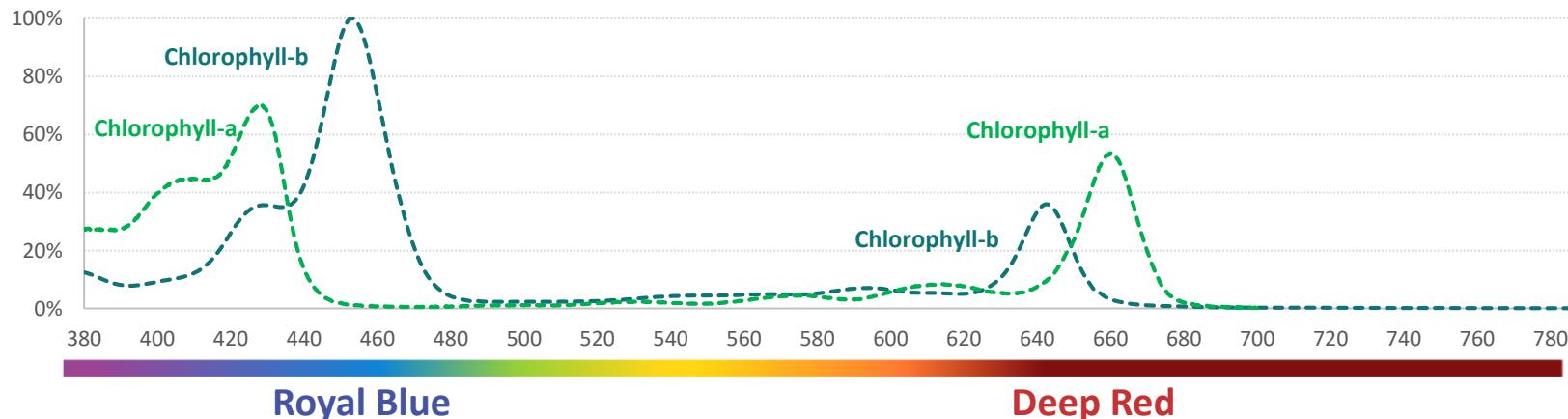


LUXEON SunPlus Series for Horticulture

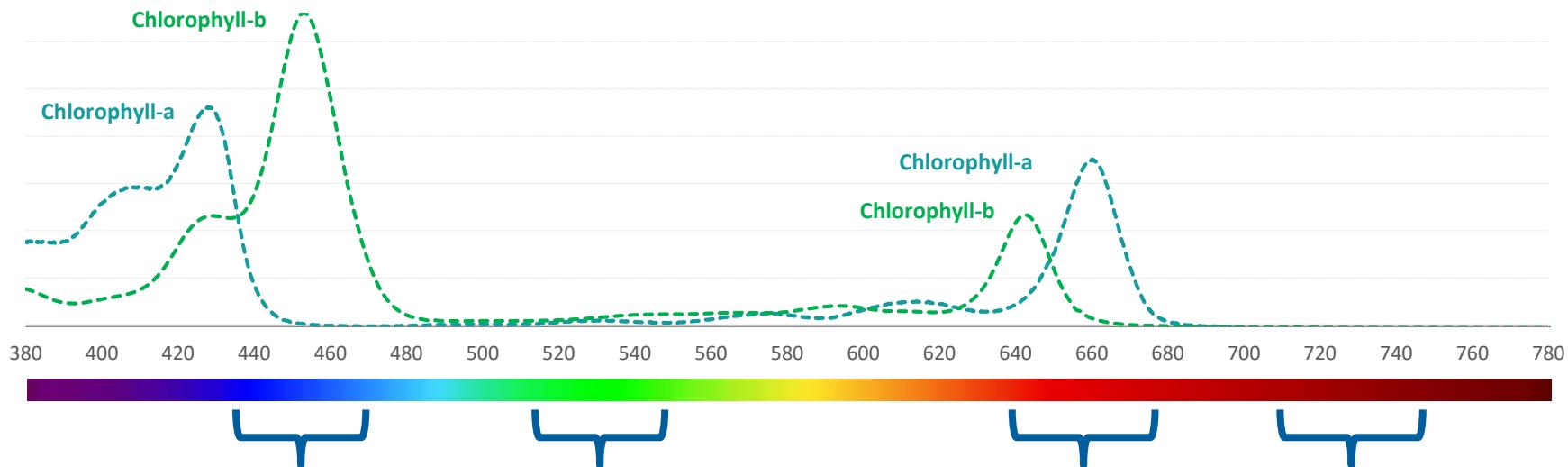
LEDs engineered to deliver the precise wavelengths of light needed to improve crop yield

- Products are purpose-built for the Horticulture market
- LUXEON SunPlus Series is the only LED tested and binned in PPF (umol/s)
- Two different package sizes: 2.0 x 2.0mm and 3.5 x 3.5mm
- Portfolio enables color tunable fixtures and single channel solutions
- Colors specifically targeted for the wavelengths where plants absorb light

Chlorophyll is the pigment found in plants that absorbs light enabling photosynthesis to take place. LUXEON SunPlus Series targets the key wavelengths where chlorophyll absorbs light.



Impact of wavelength on plants



- Important for photosynthesis
- Promotes greening and germinating seedlings
- Vegetative growth
- Supports root development and nutrient production
- Inhibits stem elongation
- Visually comfortable for human eye
- Best for visual assessment of plant
- Some vegetative growth
- Provides least amount of growth per photon
- Speeds up seed germination
- Encourages stem growth
- Essential for flowering and fruit production
- Most efficient at driving plant growth
- Stem elongation leading to taller plants but not necessarily more biomass
- Leaf growth
- Inhibits branching
- Enables day length control

Major difference between Deep Red and Far Red

- **Deep Red (660nm)**
 - Plant thinks it is being illuminated by the direct sun and tends to grow normally
- **Far Red (730nm)**
 - If the plant is illuminated mainly with 730nm the plant thinks it is growing in the shadow of another plant
 - The plant starts to react with accelerated stem growth to escape the shadow
 - Generally leads to taller plants but typically not more biomass (yield)



Mostly 660nm / some 730nm



Mostly 730nm

LUXEON SunPlus Series for Horticulture

LEDs engineered to deliver the precise wavelengths of light needed to improve crop yield

LUXEON SunPlus 20 Line



- Targets the key wavelengths where plants absorb photons (450nm & 660nm)
- High PPF to maximize the photon output of the system
- Optical design optimal for directional applications

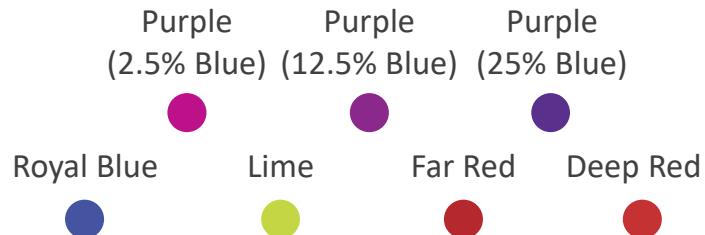
BINNED IN
PPF



LUXEON SunPlus 35 Line



- Unique Purple LED enabling a fixed spectra for quick designs
- Perfect uniformity at short distances
- Photon output per LED enables vertical farming

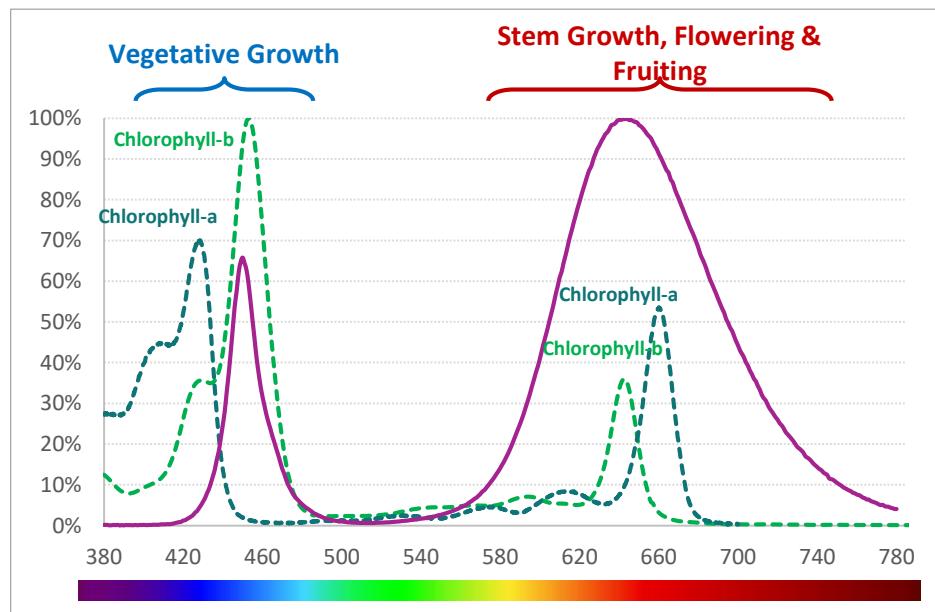


LUXEON SunPlus CoB Purple

Ease of Design and High PPF Density for a Deep Penetration into the Plant Canopy

- The LUXEON SunPlus line offers an ease of design while providing a high PPF density which is advantageous for a deep penetration into the plant canopy.
- Purple (12.5% Blue) provides the right amount of PPF in the blue wavelength (420-480nm) for the application in addition to getting PPF in the red (620-670nm) wavelength.
- Fast time to market by leveraging already existing Ecosystem

LUXEON SunPlus CoB Purple covers the growth needs of plants

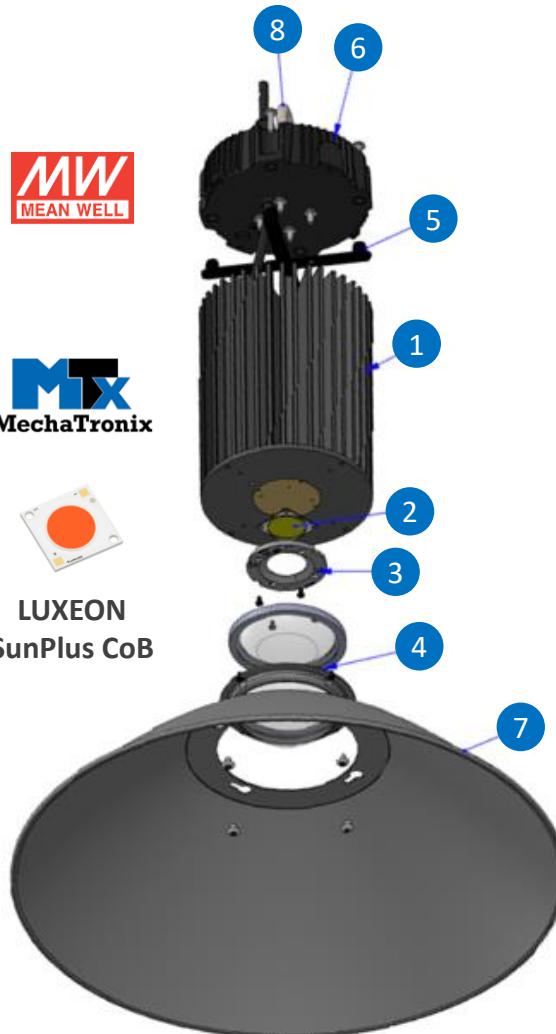


Greenhouse Fixture with 1 x LUXEON SunPlus CoB Purple

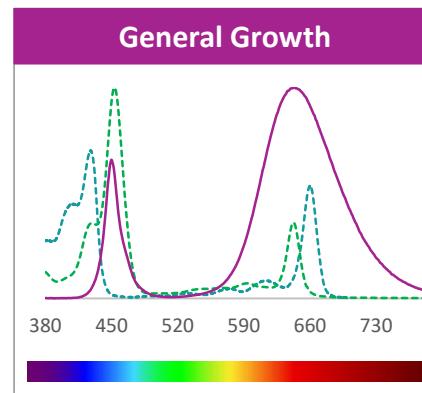
Ease of design with MechaTronix CoolBay Giga and a renowned off-the-shelf ecosystem



LUXEON
SunPlus CoB



Components		
1	Cool Frame	1 x MechaTronix CoolBay® GIGA
2	Light Source	1 x LUXEON SunPlus CoB 1211 Purple
3	Holder	1 x Coolconnect holder COB 28x28
4	Optics	1 x CoolBat Lens 60
5	Driver Accessory	1 x HBG-160 connector set
6	Driver	1 x HBG-160-60A
7	Reflector	1 x CoolBay Reflector
8	Hanging Accessory	1 x HBG driver ring-01

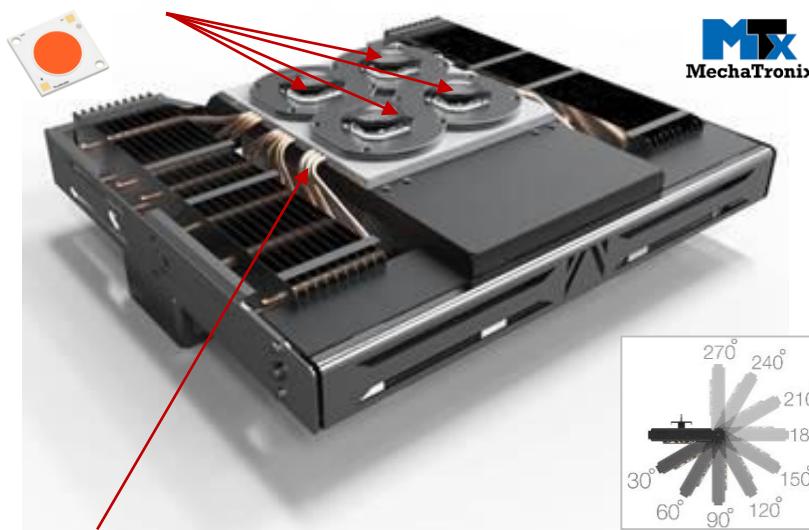


Performance	
PPF [PAR: 400nm-700nm]	120 µmol/s
Efficacy [PPF/W]	1.60 µmol/J
Drive Current	2,000 mA
Total Power	75 W
Power Input	110V-220V , 50/60Hz

Greenhouse Fixture with 4 x LUXEON SunPlus CoB Purple

Ease of design with MechaTronix CoolFin Giga and a renowned off-the-shelf ecosystem

4 x LUXEON SunPlus CoB

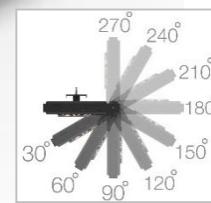


Heat pipe system

For the highest cooling performance

Tilting system

to adapt the light distribution



LUXEON SunPlus CoB Purple delivers a high PPF density with a deep canopy penetration to maximize crop yields consistently



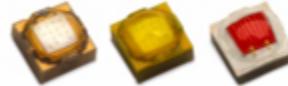
Performance

PPF [PAR: 400nm-700nm]	495 µmol/s
Efficacy [PPF/W]	1.57 µmol/J
Drive Current	2,100 mA per CoB
Total Power	315 W
Power Input	110V-220V , 50/60Hz



LUXEON SunPlus Series Applications

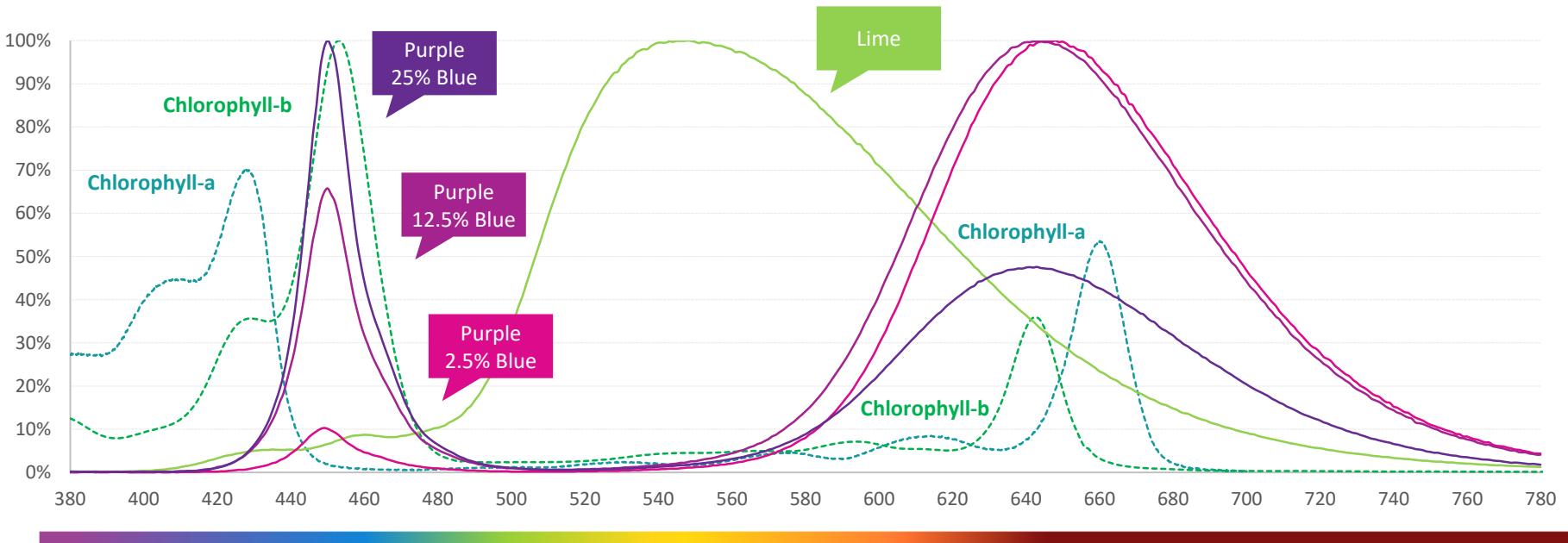
Best LED solution for three rapidly growing designs

<h3>Greenhouses</h3> 	<p>Large facilities with many high output fixtures that can extend the growing season for numerous types of crops</p>	<p>LUXEON SunPlus 20</p>  <p>LUXEON SunPlus CoB</p> 
<h3>Interweaving</h3> 	<p>Fixtures placed within the crop's canopy to supplement top lighting</p>	<p>LUXEON SunPlus 35</p> 
<h3>Vertical Farms</h3> 	<p>Numerous layers with very short distances between the fixture and plant canopy to multiply the growing area</p>	<p>LUXEON SunPlus 35</p> 

LUXEON SunPlus 35 enables ease of design with single channel solutions

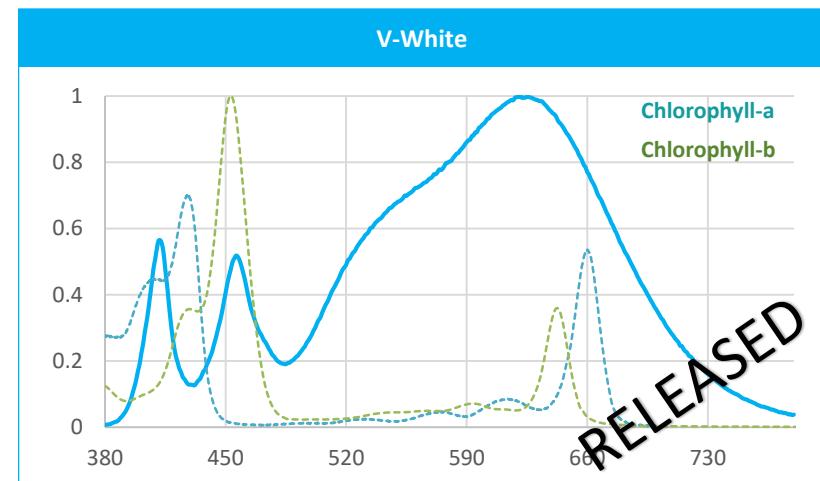
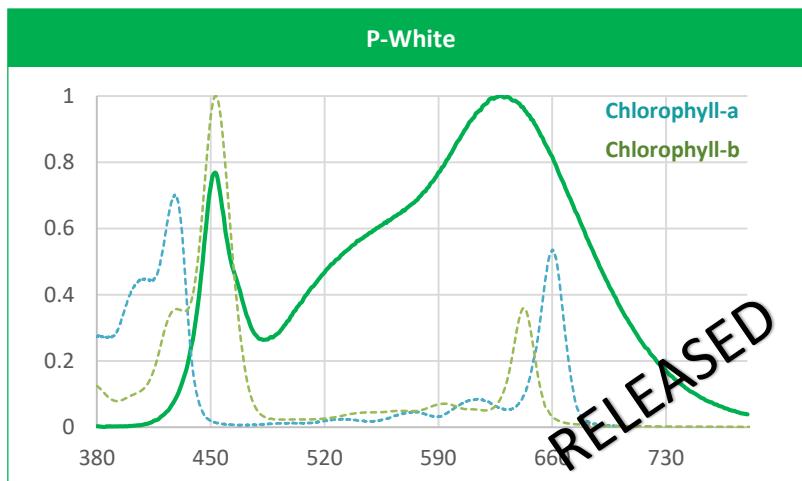
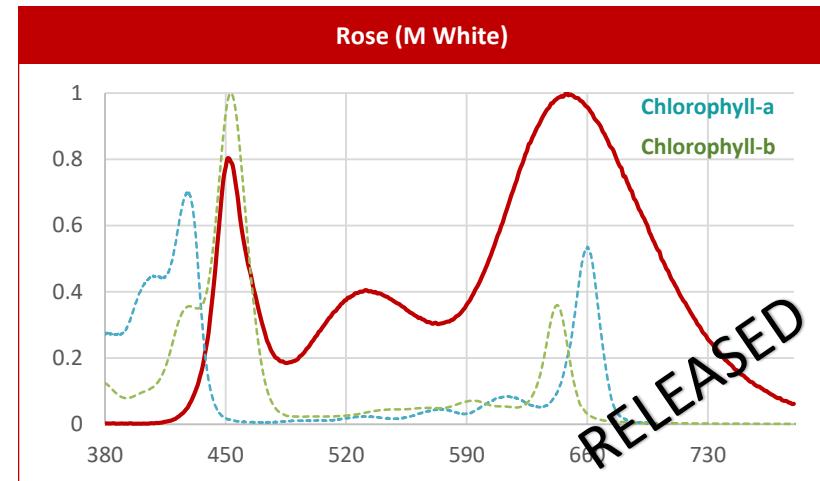
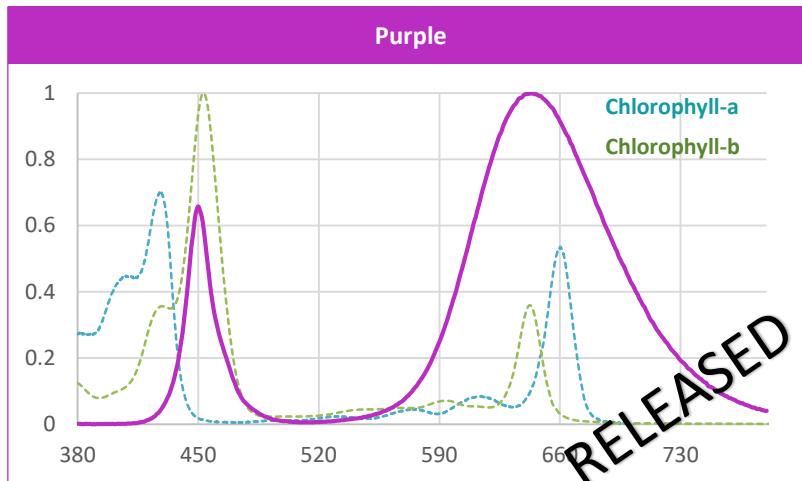
Single LEDs with fixed light recipes to cover the basic needs of plants and vegetables

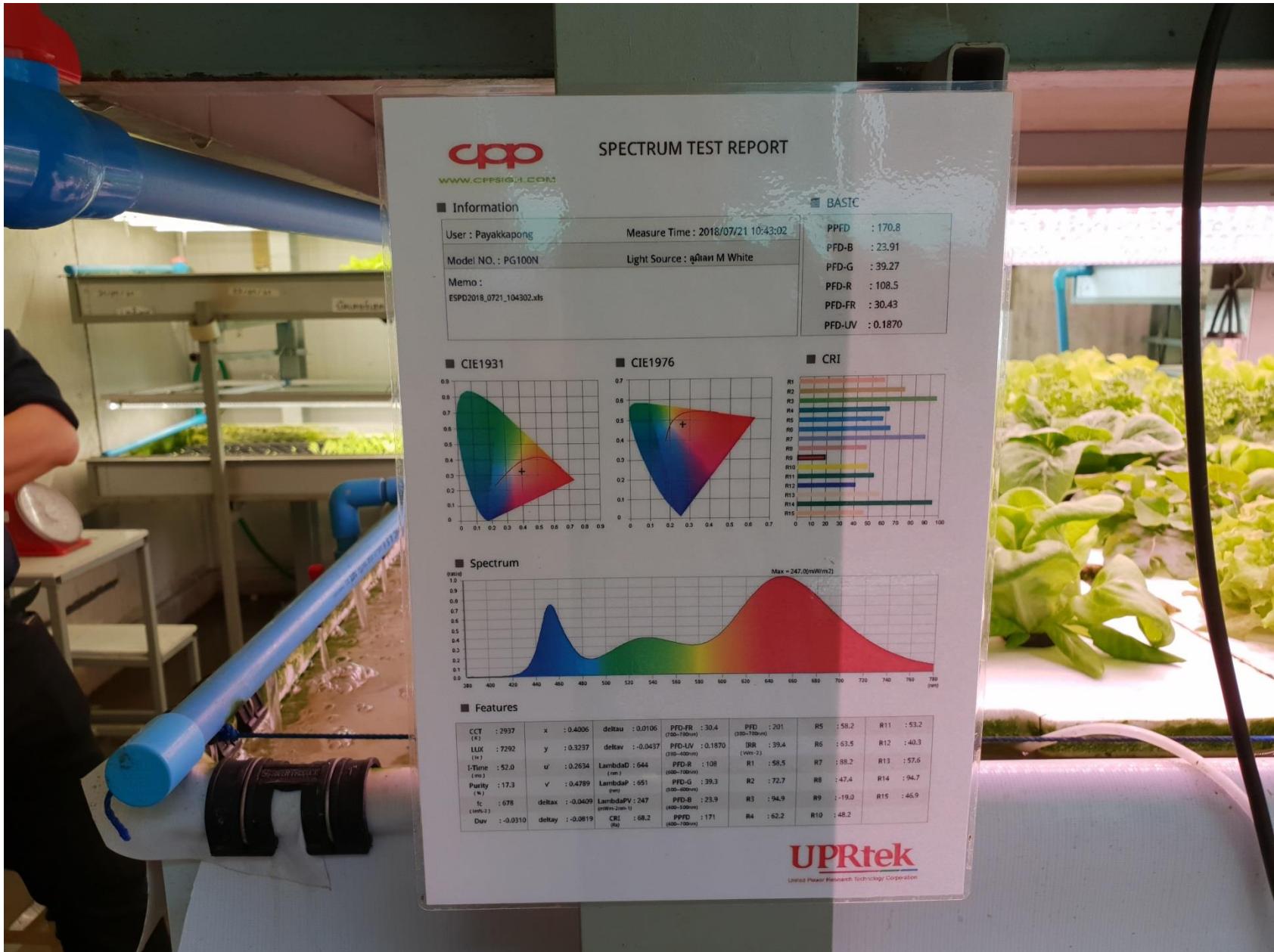
- Lime serves two purposes:
 - Fills in the spectrum
 - Lime + purple = white light: good for harvest or visual inspection



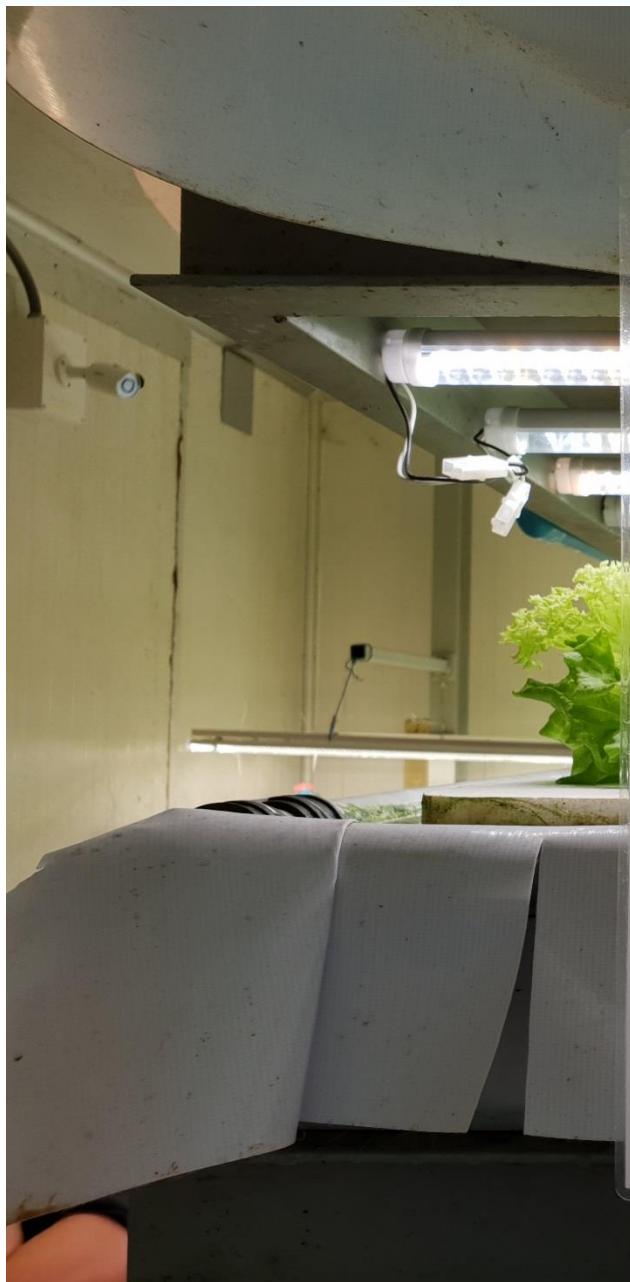
LUXEON Solutions Simplified

Spectral Offerings for Horticulture








UPRtek

United Power Research Technology Corporation



30.07.2024
14.2 %
22.8 °C
18.2 °D

KTH-798SD

DEW POINT LOGGER

SET

ON/OFF







Studies show that LUXEON CoB Spectra will increase weight of lettuce with 25% with up to 3x the leaf area compared to traditional HPS*

* Fitex, ExpertGroup, January 2018



Crops commercially successful

Basil



Rocked salad



LOLLO ROSSA & Aficion salads



Today, one of the most popular destinations (both economically and gastronomically) has been the cultivation of elite spicy herbs. Healthy eating is very fashionable. That's why current gourmet dishes and drinks abound with arugula, basil, coriander, melissa and mint. And let's not forget about the whole industry of essential oils and natural cosmetic, which very rapidly developing today. This area is actively using these herbs. Besides, basil is a serious agronomic problem today, because to achieve coloring leaf in violet color is not such an obvious task. As for the salad – all of us eat it daily almost and him popularity does not require comments.



Weight analysis

Weight analysis – is the main analysis, which is carried out in greenhouses. Analysis helps determine the commercial suitability of products. More green mass = more money!



=





Weight analysis Lolla Rossa salad

Value	One plant average weight; gr.	Accounting for main and byproducts		The total weight of each crop; gr	$\Pi_{\text{очн}} : \Pi_{\text{побочн}}$
		Average weight of leaf parts of the plant (main product); gr.	Average weight of root system with pot and substrate (byproduct); gr.		
LED 3000K, Ra 90	111	35,50	57,50	414	1:1,61
F-White + R-White	108,75	55,50	55	405	1:0,90
Rose+UV	105,50	50,50	53,25	392	1:1,05
Rose	125,75	77,25	61,25	473	1:0,79
RB/ DR/ FR	95,50	41,50	52,25	352	1:1,25
HPS	97,75	33,75	61,50	361	1:1,82



Plants biometric indicators Lollo Rossa Salad



Value	Average leaf area; cm ²	Average area of green mass; cm ²	Average height of plants; cm
LED 3000K, Ra 90	144,90	319,29	13,40
HPS	91,00	333,91	13,47
ROSE	200,41	379,44	19,10
ROSE + UV	124,25	418,01	15,62
F-White + R-White	136,54	416,04	17,70
RB/ DR/ FR	113,56	275,83	10,25



Weight analysis Aficion salad



Value	One plant average weight; gr.	Accounting for main and byproducts		The total weight of each crop; gr	$\Pi_{\text{Основное}} : \Pi_{\text{побочное}}$
		Average weight of leaf parts of the plant (main product); gr.	Average weight of root system with pot and substrate (byproduct); gr.		
LED 3000K, Ra 90	113,25 	50	63	423	1:1,26
F-White + R-White	81,75 	53,5	48,50	297	1:0,90
Rose+UV	96,50	42,25	52,75	356	1:1,24
Rose	118,75 	55,25	58,25	445	1:1,05
RB/ DR/ FR	104,25	39,75	60	387	1:1,50
HPS	98,25	36,25	58,75	363	1:1,62



Plants biometric indicators Aficion Salad

Value	Average leaf area; cm ²	Average area of green mass; cm ²	Average height of plants; cm
HPS	68,59	362,27	14,15
LED 3000K, Ra 90 	117,7	396,22	12,2
ROSE 	163,97	547,14	13,32
ROSE + UV 	101,70	355,01	13,17
F-White + R-White 	124,03	407,80	11,9
RB/ DR/ FR 	111,38	375,11	10,37





Weight analysis Basil



Value	One plant average weight; gr.	Accounting for main and byproducts		The total weight of each crop; gr	The ratio of the main production, taking into account the corresponding quantity of byproduct; (leaves: roots with pot and substrate) $\Pi_{\text{очн}} : \Pi_{\text{побочн}}$
		Average weight of leaf parts of the plant (main product); gr.	Average weight of root system with pot and substrate (byproduct); gr.		
LED 3000K, Ra 90	52,67	5,3	46,34	158	1:8,74
F-White + R-White	60,34	15,34	45,66	181	1:2,97
Rose+UV	63,00	12,67	51,66	189	1:4,07
Rose	72,00	17,34	53,33	216	1:3,07
RB/ DR/ FR	71,00	18,3	50,00	213	1:2,73
HPS	61,00	14,66	45,67	183	1:3,11



Plants biometric indicators Basil

Value	Average leaf area; cm ²	Average area of green mass; cm ²	Average height of plants; cm
LED 3000K, Ra 90	20,70	134,12	13,13
HPS	32,31	139,78	20,73
ROSE	38,90	232,65	20,05
ROSE + UV	26,09	105,65	17,66
F-White + R-White	26,77	161,30	15,8
RB/ DR/ FR	29,95	174,07	18





agricultural complex «teplichniy»,
saransk



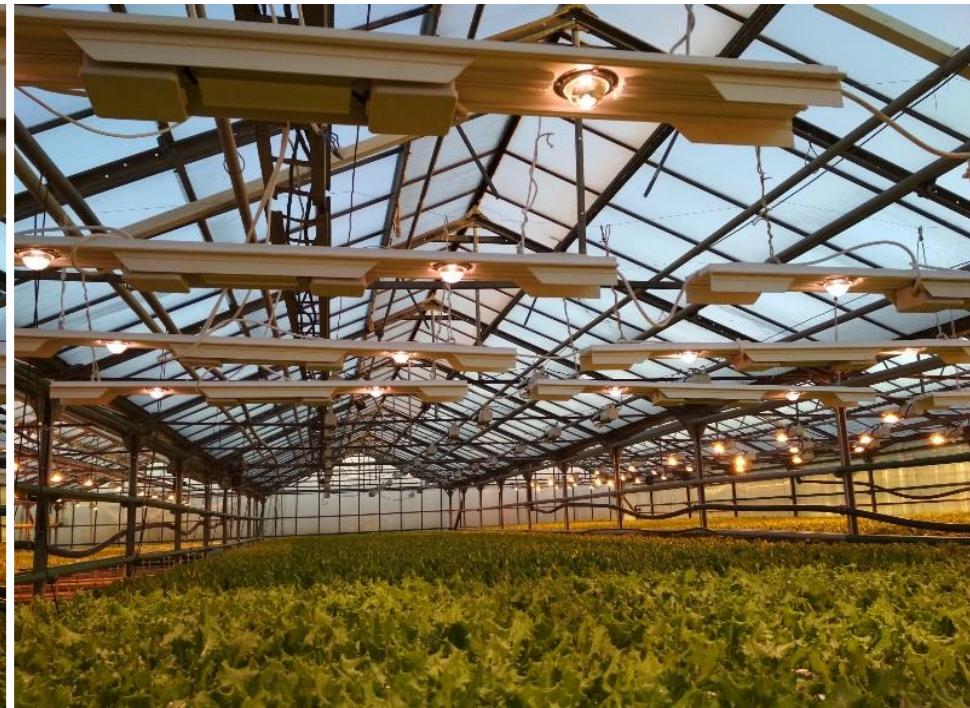


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LUXEON SunPlus 35 Purple + Lime Lettuce Growth Study Results

Combination of Purple + Lime outperforms other spectrum

- Study compared LUXEON SunPlus 35 Lime + Purple spectrum to direct LEDs & other competitor's LEDs
- Lime + Purple combination resulted in highest yield (fresh weight), anthocyanin (gives lettuce its color) and chlorophyll concentrations

Lime + Purple



Purple

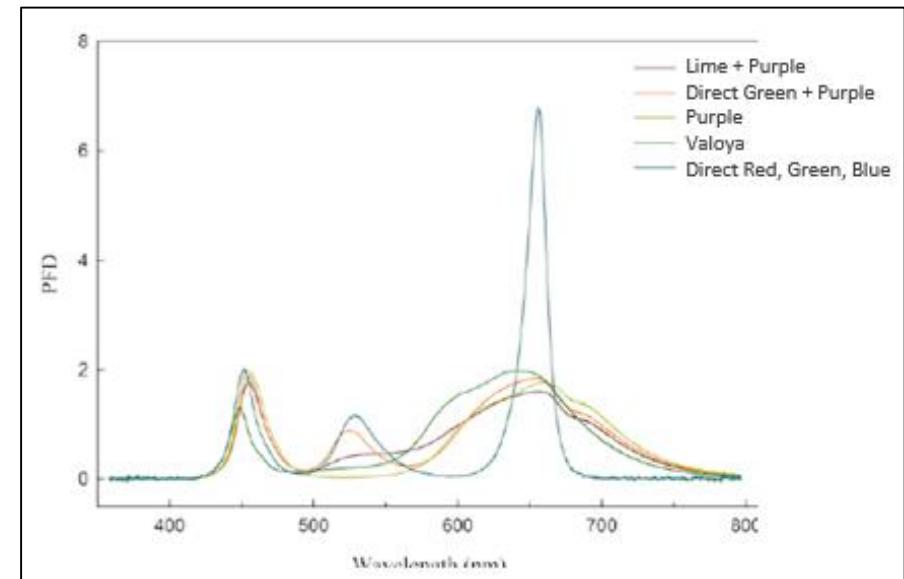


**Direct Red,
Green, Blue**



**Direct Green +
Purple**

Valoya



Typical PPFD values in Plants

Plant	Min PPFD	Typical PPFD	Max PPFD
Tomato	170	185	200
Pepper	70	100	130
Cucumber	100	150	200
Strawberries	60	70	80
Chrysanthemum	105	117	130
Rose	170	185	200
Lily	80	90	100
Freesia	70	88	105
Gerber	80	93	105
Tulip	25	33	40

- PPFD = Photosynthetic Photon Flux Density ($\mu\text{mol}/\text{m}^2\text{s}$)
- Represents the number of photons that reaches the plant within the PAR region (400 – 700nm) in any given second
- It's a spot measurement of a specific location on the plant canopy (best to take the average of several PPFD measurements to find out the true light intensity)

Lighting and Plant Characteristics

Daily Light Integral varies by plant type

- Daily Light Integral (DLI): amount of PAR received each day as a function of light intensity and duration
- Plants need a minimum amount of light per day to meet their basic biological needs, it varies based on species
- Concept: similar to a rain gauge in that a rain gauge collects the total rain in a particular location over a period of time. DLI measures the PAR received in a day
- Influences plant growth, development, yield and quality
 - E.g. can influence root and shoot growth of seedlings and cuttings
- Plants grown under too low of DLI typically have delayed growth and development

Plant	DLI (mol/m ² /day)
Tomatoes	22-30
Strawberries	22-30
Roses (Potted)	14-30
Roses (Cut Flowers)	22-30
Lettuce	14-16
Chrysanthemum (Potted)	14-30
Cucumber	22-30
Pepper	16-30

Xtralight Horticulture Fixture with LUXEON SunPlus Series

Full control to optimize the spectrum for each plant at every stage

Full Dynamic Spectrum Horticulture fixture

- Designed for all plants and stages
- Create-your-own lighting recipe to maximize the yield for each type of plant
- 8 pre-programmed lighting recipes for: seedlings, vegetative growth, flowering, general purpose, full spectrum, visual inspection and photoperiodism
- Applications: greenhouses and research



XtraLight™
Energy-Efficient Lighting Solutions

LED configuration

○ 8x LUXEON SunPlus White

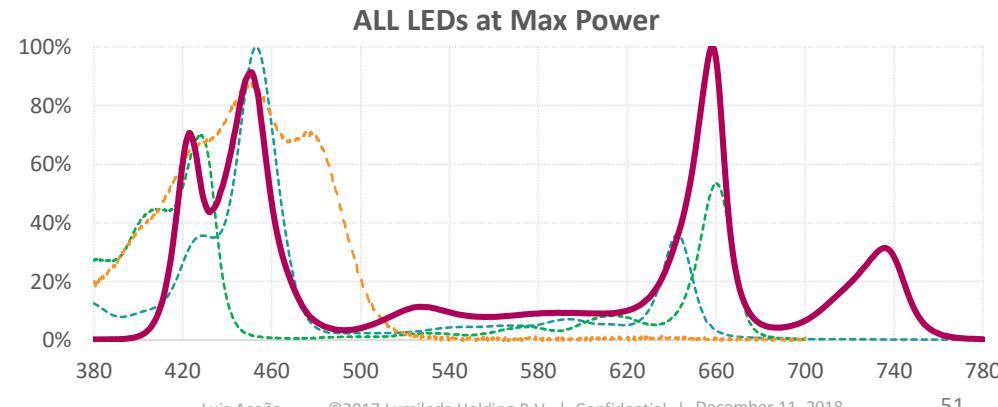
● 8x LUXEON Z 420nm

■ 16x LUXEON SunPlus Royal Blue

● 8x LUXEON SunPlus Green

● 36x LUXEON SunPlus Deep Red

● 16x LUXEON SunPlus Far Red

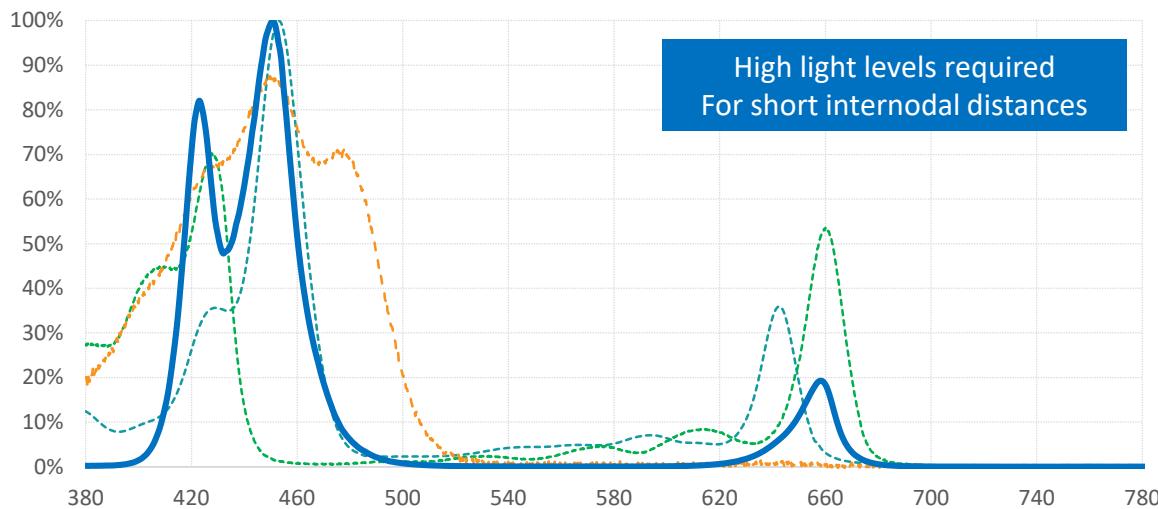


Technical Specifications

Total LEDs	100
Max PPF (400nm-700nm)	333 µmol/s
Max Power Consumption	200W
Spectrum Control	DMX (7 channels)
Input Voltage	120-220V

Xtralight Horticulture Fixture with LUXEON SunPlus Series

Light Recipe example for Seedlings



Color / Wavelength	#LEDs	Current (mA)	T _j (°C)
Cool White	8	0	85
420-425nm	8	1,500	85
Royal Blue	16	1,200	85
Green	8	0	85
PC Amber	8	0	85
Deep Red	36	120	85
Far Red	16	0	85



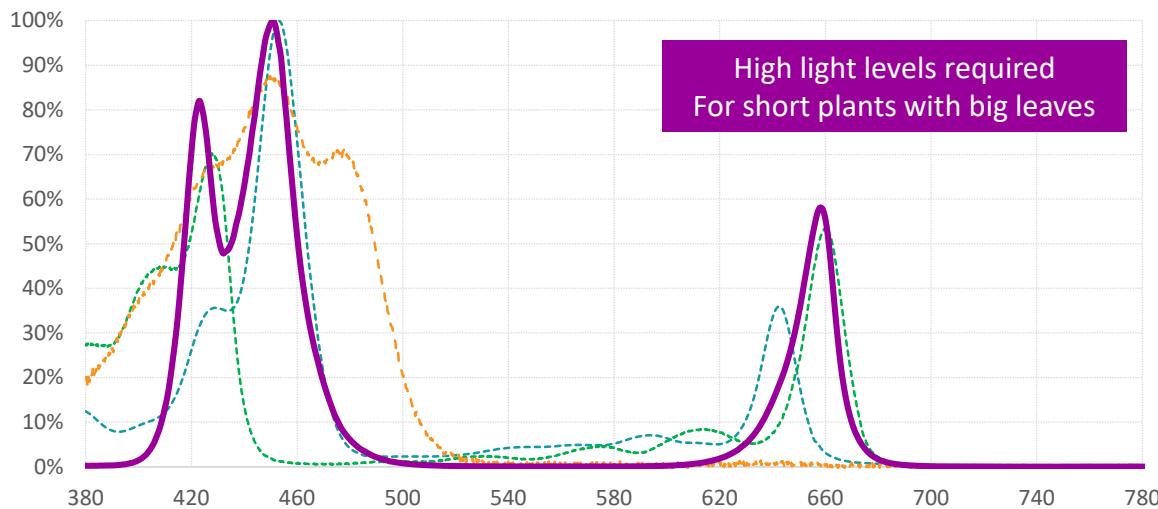
Seedlings	
PPF (400nm - 700nm)	152.12
PPF Per Elec Watt Input	1.53
Wall Plug Efficiency	40%

Blue (420nm - 480nm)	115.17
Red (620nm - 670nm)	19.42
FarRed (710nm - 750nm)	0.03
Total (380nm - 850nm)	152.49

Red / Blue Ratio	0.17
FarRed / Red Ratio	0.00
FarRed / Total Ratio	0.00
Total Elec. Power Input (W)	99.65

Xtralight Horticulture Fixture with LUXEON SunPlus Series

Light Recipe example for Vegetative Growth



Vegetative Growth

PPF (400nm - 700nm)	193.74
PPF Per Elec Watt Input	1.66
Wall Plug Efficiency	40%

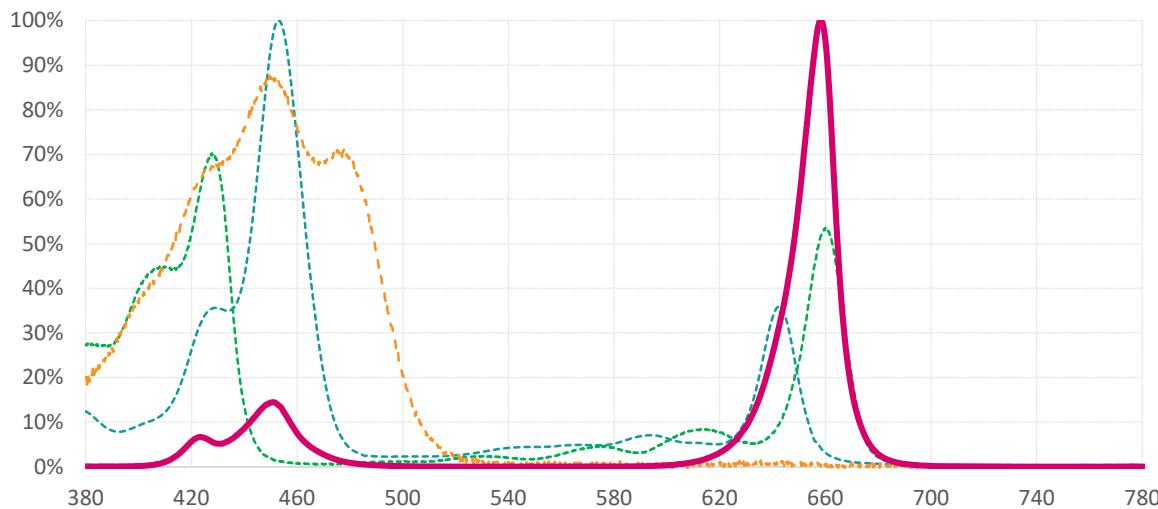
Color / Wavelength	#LEDs	Current (mA)	T _j (°C)
Cool White	8	0	85
420-425nm	8	1,500	85
Royal Blue	16	1,200	85
Green	8	0	85
PC Amber	8	0	85
Deep Red	36	350	85
Far Red	16	0	85

Blue (420nm - 480nm)	115.18
Red (620nm - 670nm)	58.53
FarRed (710nm - 750nm)	0.05
Total (380nm - 850nm)	194.19

Red / Blue Ratio	0.51
FarRed / Red Ratio	0.00
FarRed / Total Ratio	0.00
Total Elec. Power Input (W)	116.65

Xtralight Horticulture Fixture with LUXEON SunPlus Series

Light Recipe example for Flowering



Color / Wavelength	#LEDs	Current (mA)	T _j (°C)
○ Cool White	8	0	85
● 420-425nm	8	100	85
● Royal Blue	16	150	85
● Green	8	0	85
● PC Amber	8	0	85
● Deep Red	36	700	85
● Far Red	16	0	85



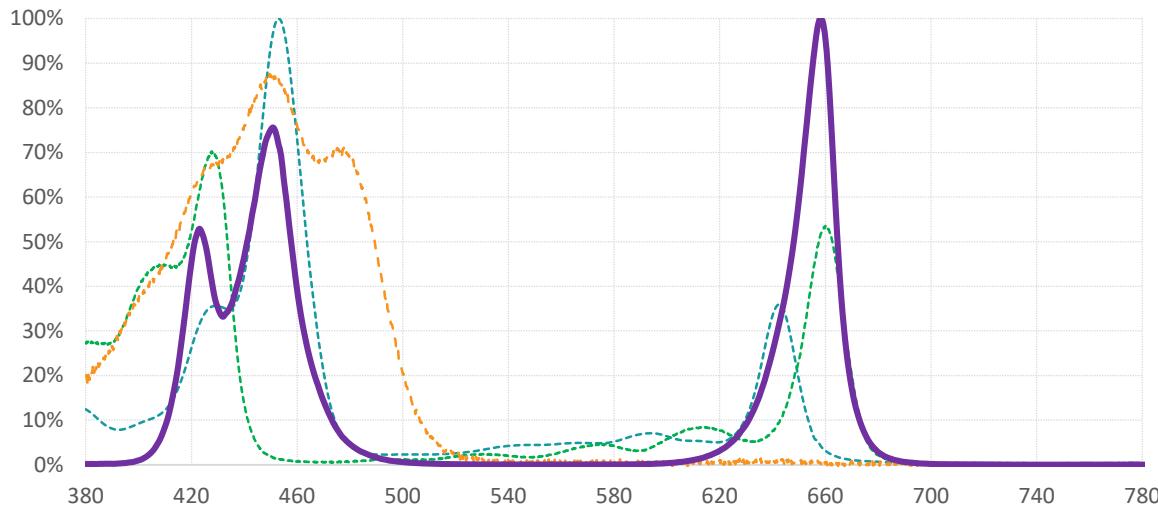
Flowering	
PPF (400nm - 700nm)	140.83
PPF Per Elec Watt Input	2.21
Wall Plug Efficiency	43%

Blue (420nm - 480nm)	16.87
Red (620nm - 670nm)	114.95
FarRed (710nm - 750nm)	0.08
Total (380nm - 850nm)	141.08

Red / Blue Ratio	6.81
FarRed / Red Ratio	0.00
FarRed / Total Ratio	0.00
Total Elec. Power Input (W)	63.58

Xtralight Horticulture Fixture with LUXEON SunPlus Series

Light Recipe example for General Purpose



Color / Wavelength	#LEDs	Current (mA)	T _j (°C)
Cool White	8	0	85
420-425nm	8	1,000	85
Royal Blue	16	1,000	85
Green	8	0	85
PC Amber	8	0	85
Deep Red	36	700	85
Far Red	16	0	85



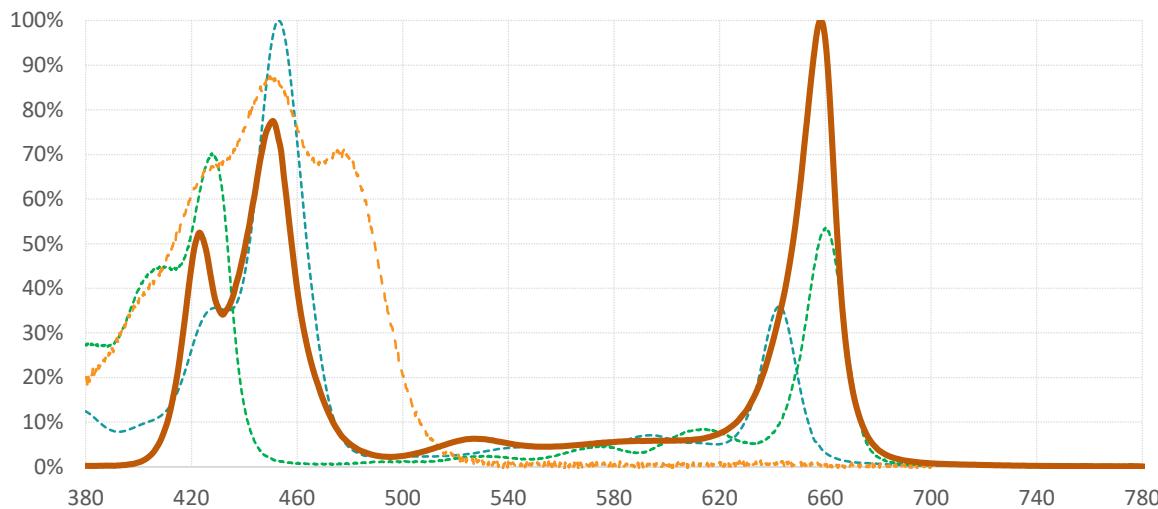
General Purpose	
PPF (400nm - 700nm)	230.20
PPF Per Elec Watt Input	1.85
Wall Plug Efficiency	41%

Blue (420nm - 480nm)	95.62
Red (620nm - 670nm)	114.98
FarRed (710nm - 750nm)	0.09
Total (380nm - 850nm)	230.67

Red / Blue Ratio	1.20
FarRed / Red Ratio	0.00
FarRed / Total Ratio	0.00
Total Elec. Power Input (W)	124.61

Xtralight Horticulture Fixture with LUXEON SunPlus Series

Light Recipe example for Full Spectrum



Color / Wavelength	#LEDs	Current (mA)	T _j (°C)
○ Cool White	8	500	85
● 420-425nm	8	1,000	85
● Royal Blue	16	1,000	85
● Green	8	500	85
● PC Amber	8	700	85
● Deep Red	36	700	85
● Far Red	16	0	85



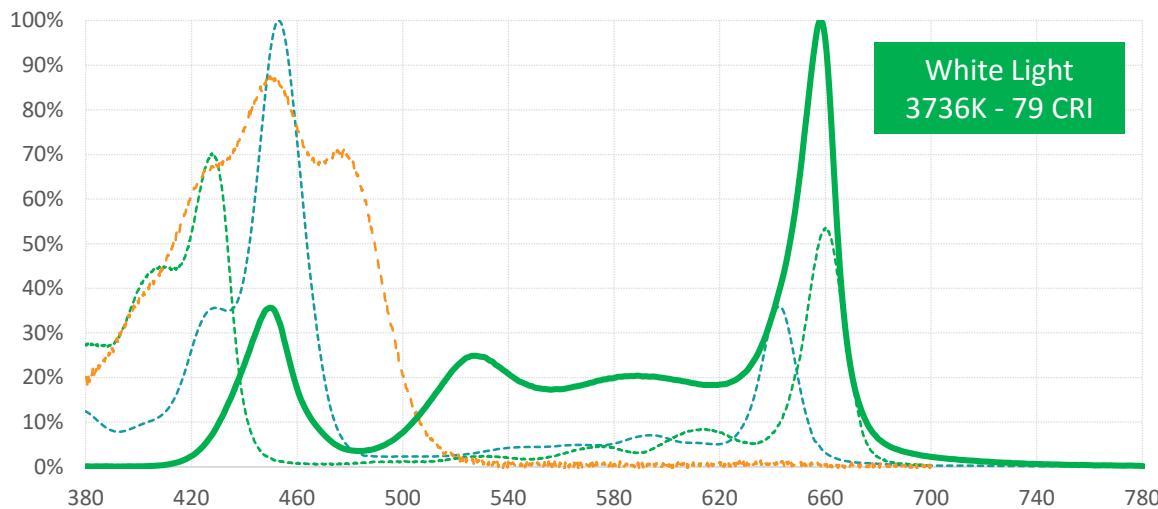
General Purpose (Full Spectrum)	
PPF (400nm - 700nm)	275.24
PPF Per Elec Watt Input	1.70
Wall Plug Efficiency	38%

Blue (420nm - 480nm)	99.74
Red (620nm - 670nm)	122.90
FarRed (710nm - 750nm)	0.75
Total (380nm - 850nm)	276.90

Red / Blue Ratio	1.23
FarRed / Red Ratio	0.01
FarRed / Total Ratio	0.00
Total Elec. Power Input (W)	162.20

Xtralight Horticulture Fixture with LUXEON SunPlus Series

Light Recipe example for Visual Inspection



Visual Inspection	
PPF (400nm - 700nm)	142.18
PPF Per Elec Watt Input	1.31
Wall Plug Efficiency	27%

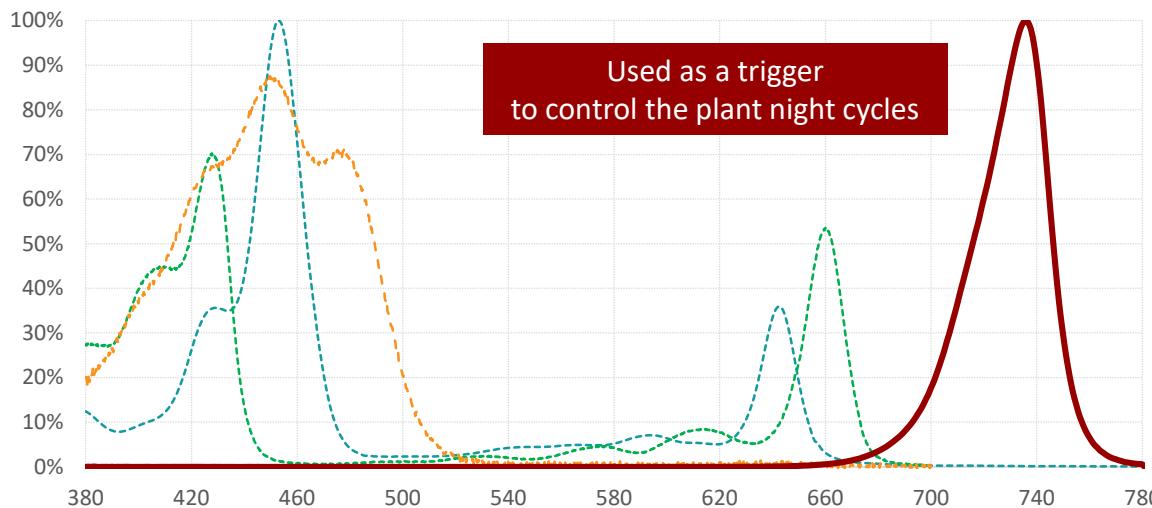
Color / Wavelength	#LEDs	Current (mA)	T _j (°C)
○ Cool White	8	1,200	85
● 420-425nm	8	0	85
● Royal Blue	16	100	85
● Green	8	1,200	85
● PC Amber	8	1,200	85
● Deep Red	36	300	85
● Far Red	16	0	85

Blue (420nm - 480nm)	18.04
Red (620nm - 670nm)	63.10
FarRed (710nm - 750nm)	1.15
Total (380nm - 850nm)	144.27

Red / Blue Ratio	3.50
FarRed / Red Ratio	0.02
FarRed / Total Ratio	0.01
Total Elec. Power Input (W)	108.51

Xtralight Horticulture Fixture with LUXEON SunPlus Series

Lighting Recipe example for Controlling Photoperiodism



Controlling Photoperiodism	
PPF (400nm - 700nm)	4.28
PPF Per Elec Watt Input	0.11
Wall Plug Efficiency	30%

Color / Wavelength	#LEDs	Current (mA)	T _j (°C)
Cool White	8	0	85
420-425nm	8	0	85
Royal Blue	16	0	85
Green	8	0	85
PC Amber	8	0	85
Deep Red	36	0	85
Far Red	16	700	85

Blue (420nm - 480nm)	0.01
Red (620nm - 670nm)	0.30
FarRed (710nm - 750nm)	58.05
Total (380nm - 850nm)	71.96

Red / Blue Ratio	40.49
FarRed / Red Ratio	191.91
FarRed / Total Ratio	13.19
Total Elec. Power Input (W)	39.83

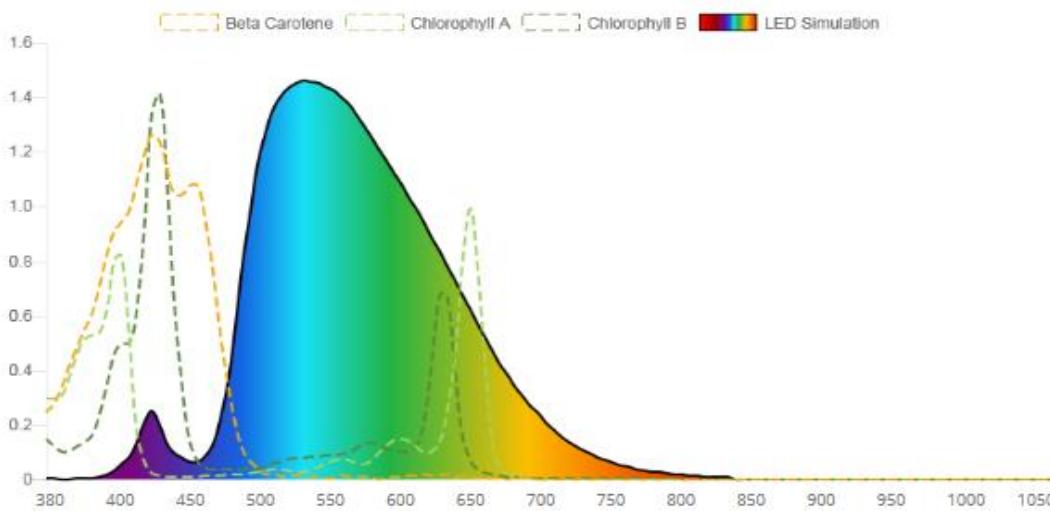
Horticulture Lighting Calculator

LED family	Color	Part Number	# LEDs	Current [mA]	T _J [°C]
LUXEON SunPlus 35		L1SP-LME0003500000 (Lime)	300	100 [20 - 200]	25 [25 - 125]
LUXEON SunPlus 35		L1SP-PRP1003500000 (12.5% Blue)	50	100 [30 - 300]	25 [25 - 125]

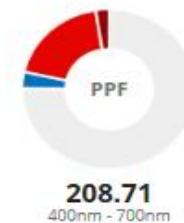
[Add Product](#)
[Calculate](#)

Forward Voltage	Photosynthetic Photon Efficacy	Electrical Power
3.05 V	1.96 μmol/J	91.5 W
2.8 V	2.1 μmol/J	14.0 W

SPECTRAL DISTRIBUTION [\[Download Results\]](#)



TOTAL PERFORMANCE



μmol/J	WPE
1.98 micromol/J	42.8 %
Elect. Power	R-B Ratio
105.50 W	5.76

TOTAL	380nm - 850nm	218.34 μmol/s
Blue	420nm - 480nm	6.89 μmol/s
Red	620nm - 670nm	39.73 μmol/s
FarRed	710nm - 750nm	5.23 μmol/s



LUXEON SunPlus —SERIES—

LEDs created with
one market in mind:

Horticulture

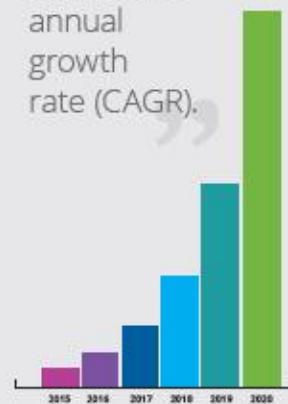


“LED horticultural luminaires are forecast to experience **ASTRONOMICAL GROWTH** over the next five years.”

— Navigant Research 2015



Unit sales are forecast to grow between 2015 and 2020 at an 83.3% compound annual growth rate (CAGR).



— Navigant Research 2015

 **LUMILEDS**

To find out how Lumileds can help you get your share of the lucrative horticulture market, visit lumileds.com/horticulture.

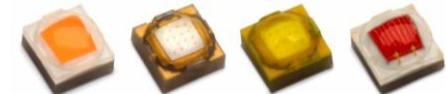
LUXEON Color Family Overview

Several options to meet the different application needs

LUXEON C

Domed
High lumen output

- Maximize lumen output
- One focal length across all colors
- Largest color gamut in the industry
- Ideal for color mixing applications

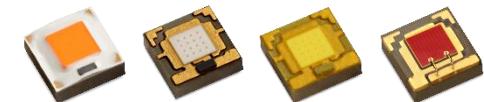


New

LUXEON CZ

Undomed
Maximum punch

- Maximize punch
- Leverages LUXEON C technology and footprint
- One focal length across all colors



Matrix Platform

Integrated solutions

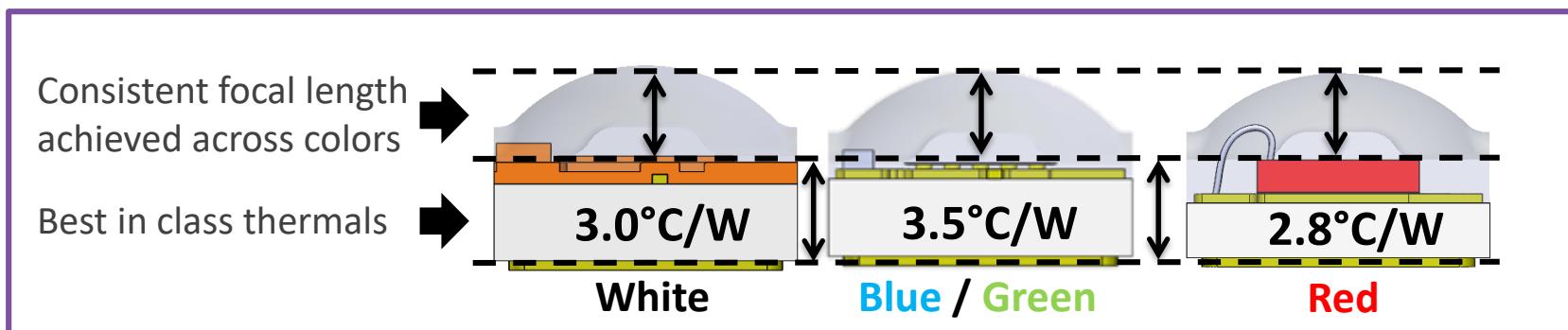
- Offers unique, intelligent LED mixing together with integrated light guides, drivers, connectivity, controls and/or dimming electronics
- Combines high performance solutions with value engineering
- Simplifies the customer supply chain



LUXEON C Color Line

Compact color emitters for high lumen output and flawless color mixing

- Domed emitter providing high lumen output
- Consistent focal length for ease of color mixing in any system
- Lowest thermal resistance enabling brighter, lower cost, more efficient systems
- Completely hot tested eliminating unwanted surprises in color shift; all colors and whites @ 85°C Tj
- Broadest color portfolio ensuring largest color gamut



LUXEON C Maximizes Flux Output

Competitive performance across the entire color gamut

	LUXEON C	Cree XQE HD	Osram SSL	Nichia 119 / 219
Red	47	45	46	47
Green	115	90	117	134
Blue	41	40	45	44
PCA	94	78	100	106
3000K/80	102	100	114	138

Data listed @350mA/85C

- LUXEON C flux performance enables competitive designs in any application
- Don't forget about efficacy:
 - Combination of low Vf and industry lowest thermal resistance ensures high efficacy at the system level

Case Study

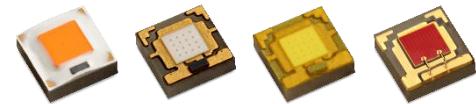
Flinders Street Station (Melbourne) – LUXEON Rebel Colors, C and 3535L Colors



New

LUXEON CZ Color Line

Maximum punch, narrow beam angles in over 20 colors



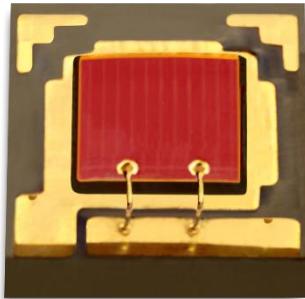
- Industry leading punch (cd/lm)
- Eliminate cross talk in densely packed applications
- Same focal height for all colors
- Low thermal resistance and isolated thermal pad for better thermal management
- Full color palette including white
- Utilizes the same building blocks as LUXEON C
- 100% hot tested at 350mA/85°C
- Small 2.0x2.0mm package for packing density



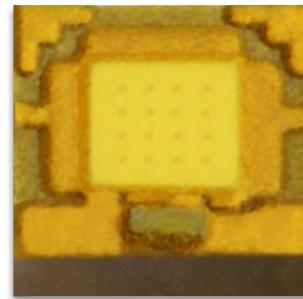


LUXEON CZ Color Line

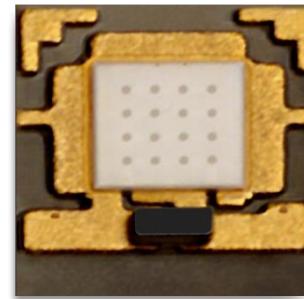
Industry's most complete color gamut



Amber*



2700K/80CRI



Violet



PC Amber*

Red-Orange*

3000K/80CRI*

Royal Blue*

Red*

4000K/80CRI

Blue*

Deep Red

4000K/70CRI*

Cyan*

Far Red

5000K/70CRI*

Green*

5700K/70CRI*

5700K/90CRI

6500K/70CRI

Lime

Mint*

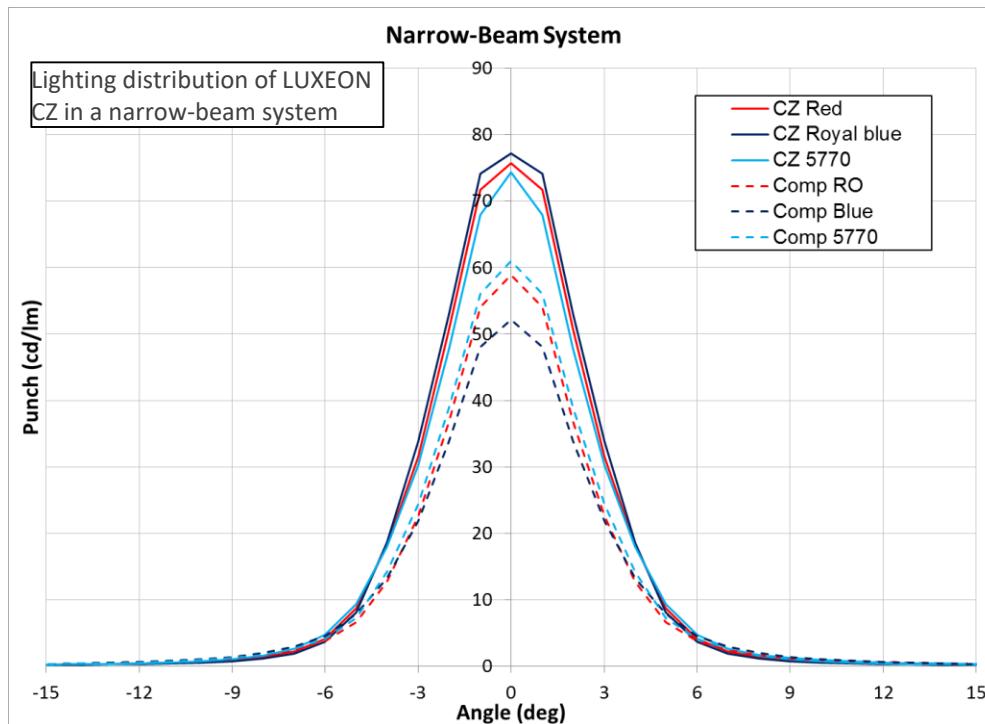
*Products available at launch.

Remaining colors to be released within 1H 2018.

LUXEON CZ Maximizes Punch in Narrow Beam Applications

Industry leading punch offering over 45% advantage vs other undomed emitters

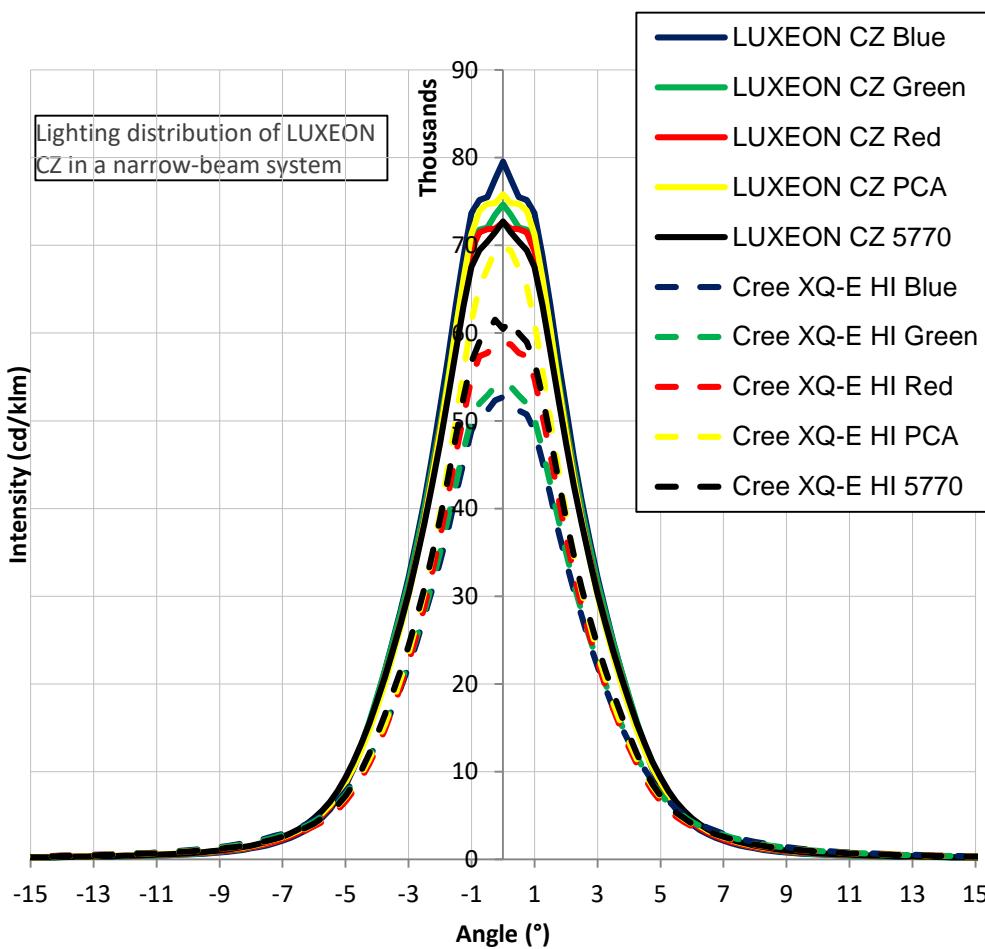
- LUXEON CZ punch outperforms other undomed emitters across the color gamut
- Small source size simplifies narrow beam optics design



	LUXEON CZ cd/lm	Competition cd/lm	Comparison %Δ (cd/lm)
Red/RO	76	59	28%
RB/Blue	77	52	48%
5770	74	61	21%

Comparing Punch in a System

Industry leading punch offering up to a 48% advantage vs other undomed emitters



	LUXEON CZ	Competition	Comparison
	cd/lm	cd/lm	%Δ (cd/lm)
RB/Blue	79	53	48%
Green	75	55	36%
Red/RO	73	58	26%
PCA	75	70	7%
5770	75	61	23%

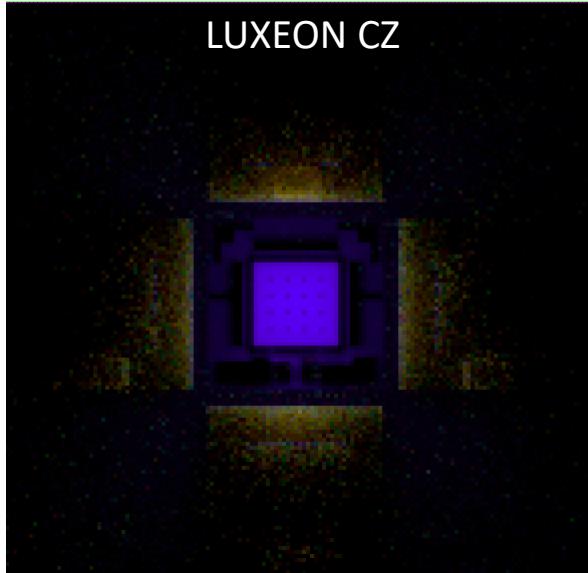
- LUXEON CZ punch outperforms other undomed emitters across the color gamut
- Small source size simplifies narrow beam optics design
- Less variation in cd/lm helps keep beam width consistent and minimizes halos when color mixing

Crosstalk Challenges Resolved

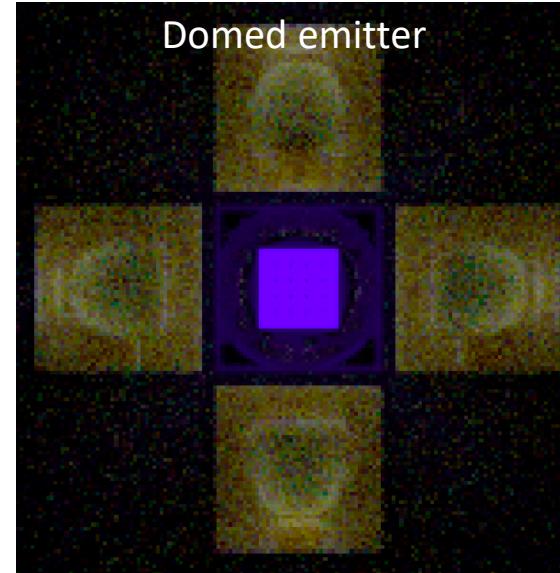
Eliminate crosstalk in tightly packed applications

- An example of one Royal Blue emitter surrounded by 4 white emitters. The Royal Blue emitter is the only LED in the group with power
- The forwarded directed light of LUXEON CZ ensures the phosphor is not being activated in the white emitters
- This enables the ability to easily achieve the desired color point in tightly packed applications

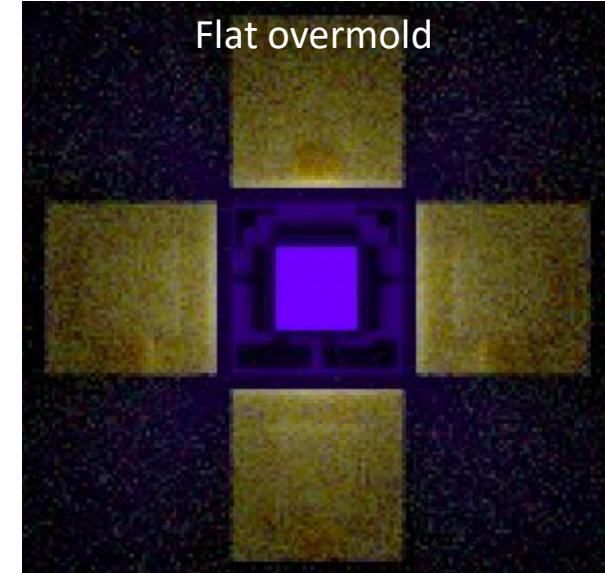
LUXEON CZ



Domed emitter



Flat overmold



LUXEON 3535L Color Line

Lumileds LEDs that deliver the right amount of color you need. No more. No less.



- Full color palette for a wider spectrum range, including Phosphor Converted Amber and Lime
- Ideal color option for cost effective designs in an industry standard 3535 package
- Same focal height as other LUXEON Color family parts – optically compatible
- Single die and single source architecture for optical control



LUXEON Color Family Overview

Color	LUXEON C	LUXEON CZ	LUXEON 3535L Colors	LUXEON 2835 Colors
Violet				
Royal Blue	●	●	●	●
Blue	●	●	●	●
Cyan	●	●		
Green	●	●	●	●
Amber	●	●		
PC Amber	●	●	●	●
Red-Orange	●	●	●	●
Red	●	●	●	●
Deep Red	●	●		●
Far Red	●	●		●
Lime	●	●	●	●
Mint	●	●		

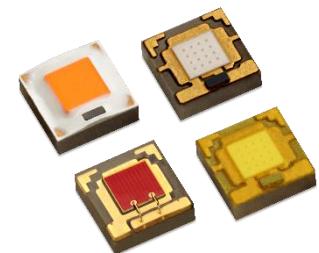
LUXEON Color Family.....In Conclusion

Why Lumileds?

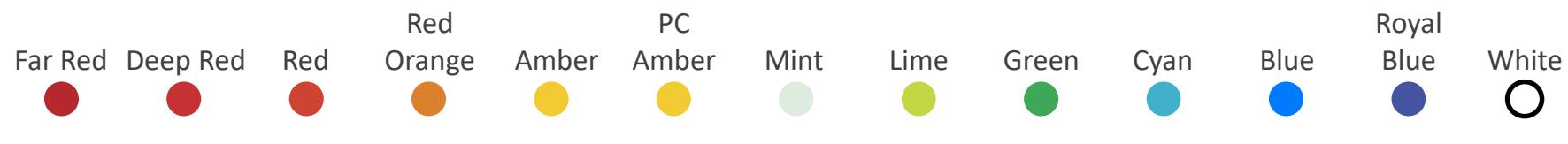
- Best in Class:
 - Industry leading punch – LUXEON CZ
 - Competitive flux performance – LUXEON C
 - Broadest color gamut in the industry
 - Industry's lowest thermal resistance
 - Eliminate cross talk
 - Same focal length across all colors
- Reduce R&D costs and accelerate time to market using our Matrix solutions and application support



LUXEON C



LUXEON CZ



Starboards available to support
performance evaluation



LUMILEDS

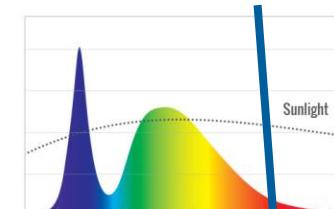
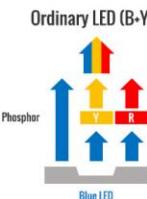
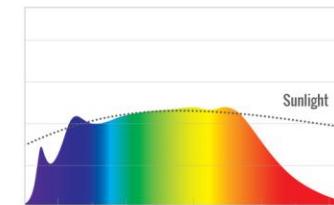
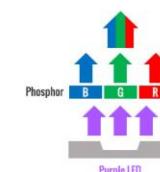
Sunlike LEDs

- SSC is making use of violet pumped LEDs, just like our CrispWhite solution.
- They “fill in” the gap in the spectrum between the blue and the phosphor conversion with blue phosphor, enabling high CRI values, but reducing efficacy significantly.
- No evidence on health benefits (claimed by SSC)
- Lumileds is able to achieve these spectrums, but has not seen the market feedback for this.



SEOUL SEMICONDUCTOR

SunLike
Powered by

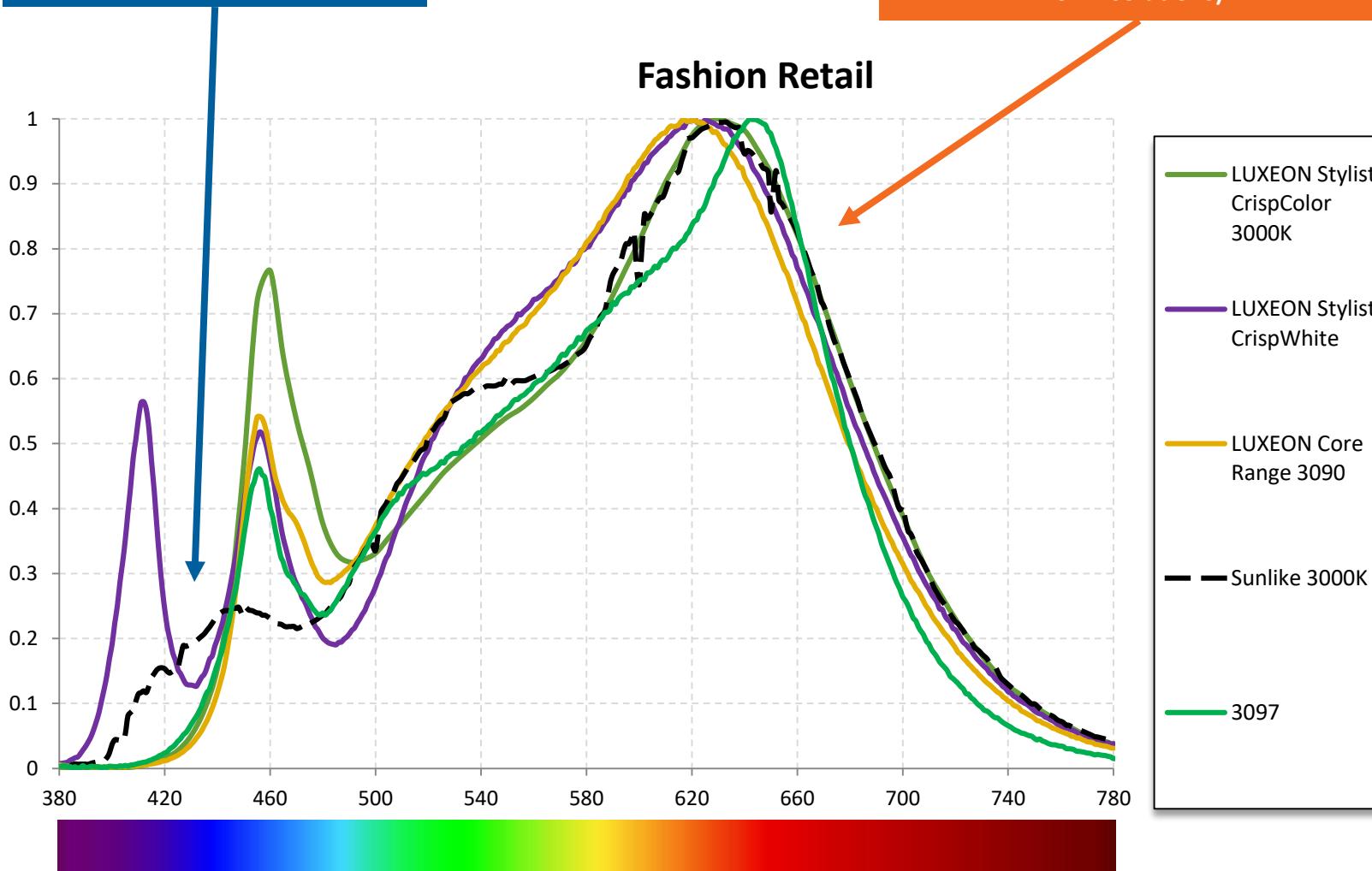


Seoul Semi / Toshiba Materials

This is 5000K!

Sunlike tries to fill in the gap in the violet 400-450nm (like Soraa), Lumileds was leading this 5 years ago with CrispWhite that is still available

The phosphor conversion makes sure there is a high CRI. Check with the customer what matters in terms of rendering (CRI, TM30 etc, we have our own solutions)



Follow up questions versus Sunlike

Positioning

What does the customer want?

- Is it TM30?
 - CrispColor is better
- Is it CRI?
 - We have a 98CRI as well (green line)
- Is it the violet part of the spectrum
 - Look at Crisp White
- Explain that there is a large flux and efficacy penalty to add blue into this spectrum.
- Lumileds has narrow band red phosphors that can limit this flux penalty in their latest Gen 4 versions that is at least 4% better than all other competitors.



SEOUL SEMICONDUCTOR

logovaults

Nichia Optisolis



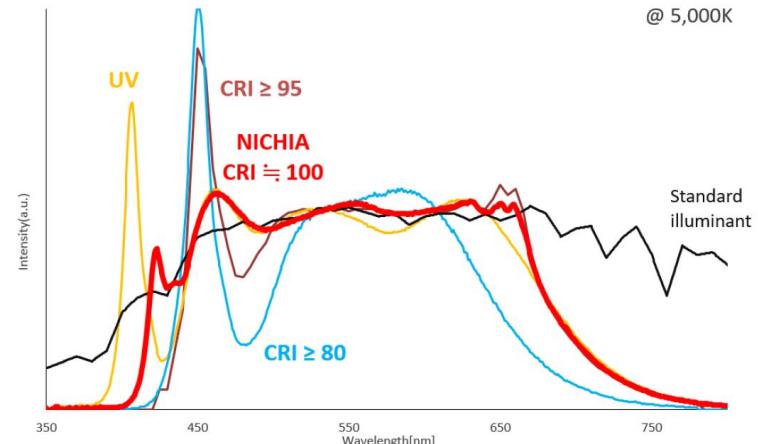
- There is a 37% efficacy difference between CRI 80 and the Optisolis versions
 - Lumileds has a 12% difference in gen 4 versus 80CRI

Reaching the World's First CRI \approx 100 LED ^{13/25}

NICHIA CRI \approx 100 vs. UV
 Higher Efficacy; Better CRI; Spectrum improvement; No UV radiation

Reaching the World's First CRI \approx 100 LED ^{14/25}

Approach	Chip	Phosphor 1	Phos. 2	Phos. 3	Phos. 4	Phos. 5	Efficacy [%]
NICHIA CRI \approx 100 Ri \geq 90 (R1 to R15)	420nm	Apatite	Silicate based phosphor	LuAG	SCASN	Improved MGF	63
NICHIA CRI \geq 95	Blue	LuAG	SCASN	Silicate-based phosphor	Improved MGF	-	75
UV Ri \geq 90 (R1 to R15)	405nm	Apatite	Silicate based phosphor	LuAG	SCASN	-	54
CRI \geq 80	Blue	YAG	SCASN			-	100



Emission spectra of CRI \geq 80 and CRI \approx 100 LED