DLC

Stakeholder
MEETING
2017

Harvesting the Benefits of Horticultural Lighting

Horticultural Lighting

- As legislation expands across the country, horticultural grow facilities are becoming the fastest-growing load for DLC-member utilities.
  - New facilities → New load
- More and more facilities are coming online.
  - Addressing product performance and energy consumption is critical.

Near-Term Plans

Participate in industry working groups on standards development and track industry activities and publications

- ASABE
- IES
- LRC
- GLASE
- Others

Create home on DLC website to explain technology and market status, highlight product considerations, and provide DLC updates

- Launching in August

Investigate (interim) approach for qualifying products and reporting performance data

- Draft proposal Q1 2018

Potential Market Paradigm

1. Industry-developed guidance document will lay out parameters that need to be known/considered to determine installation/lighting needs
2. Grower/Specifier will take this information to build a spec for product selection
3. DLC QPL will have verified list of products meeting minimum thresholds
    a) Published performance data
    b) Enable utility incentives

Potential Market Paradigm

What Goes In To a DLC Spec?

1. What types of products need to be covered?
   a) How should they be structured?
2. What are the metrics?
   a) Which metrics should have minimum thresholds?
3. Where to set the minimum thresholds?
   a) What performance will meet customer needs and save energy?
4. Is there a standardized test procedure?
   a) Are there labs accredited to that standard?

Beyond the Spec

- Determining energy savings
  - How will utilities set baselines?
- Informing product selection
  - Will the growers know what their plants' needs are?
    - Various stages of cultivation
    - Different crops
- Driving adoption
  - Will energy savings be the motivating factor?

Panelists

Philip Smallwood

Strategies Unlimited

Travis Williams

Fluence Bioengineering

Doug Oppedal

Evergreen Consulting

PENNWELL LED & LIGHTING NETWORK

NORTH AMERICAN HORTICULTURAL LIGHTING MARKET OVERVIEW

PENNWELL LED & LIGHTING NETWORK

PENNWELL LED & LIGHTING NETWORK

Technology

LEDs MAGAZINE

LEDs MAGAZINE SAPPHIRE AWARDS 2017

Strategies in Light

Strategies Unlimited

Application

THE LED SHOW

LUX live 2016
REVOLUTIONISE YOUR LIGHTING

LUX Awards 2016

Inspiration

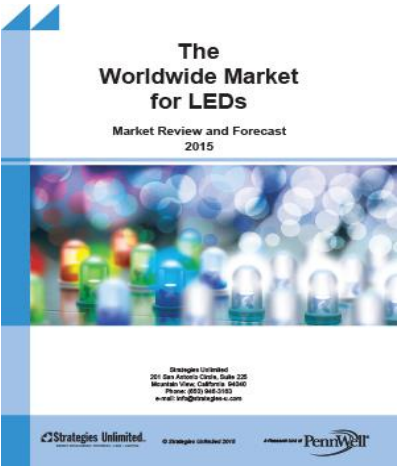
LIGHTING
ILLUMINATION IN ARCHITECTURE

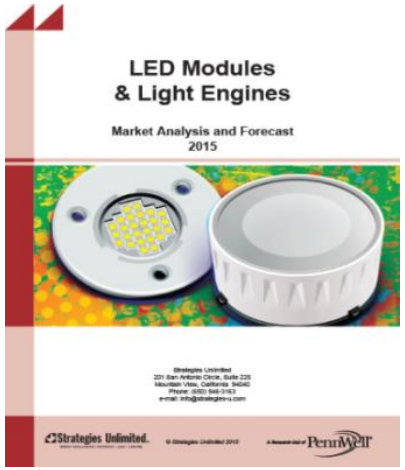
LIGHTING DESIGN AWARDS 2017

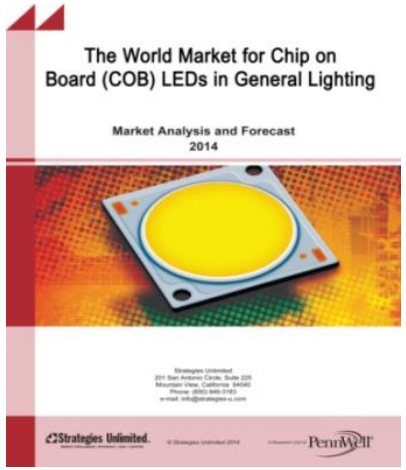
lightspace dot london 2016

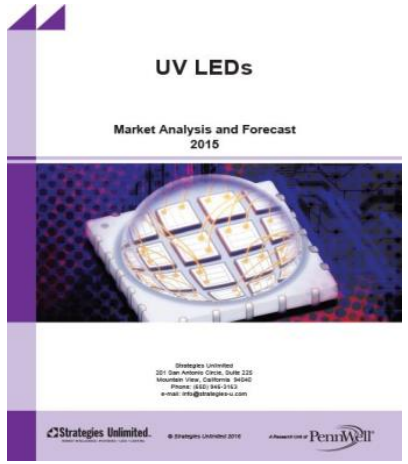
lightspace california 2017

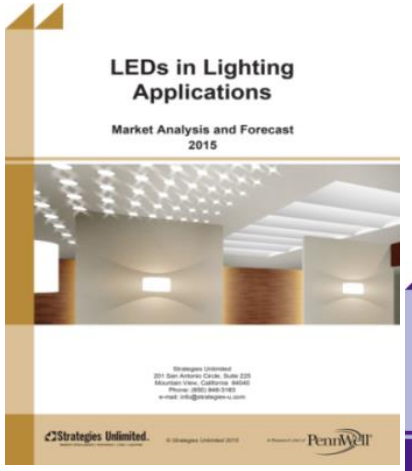
Markets Covered

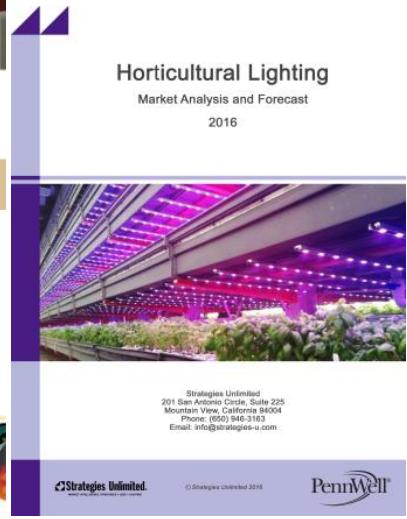


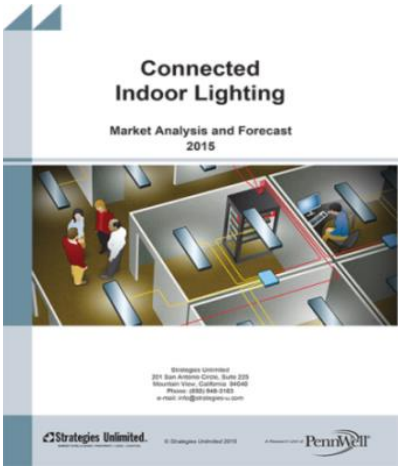


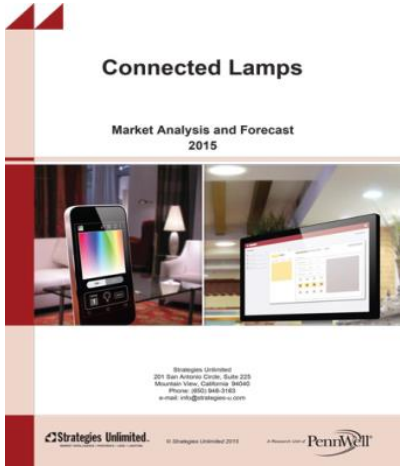


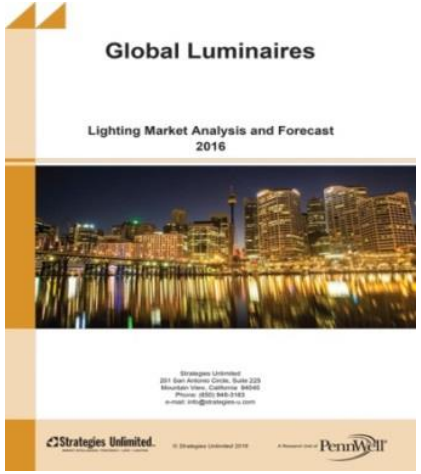


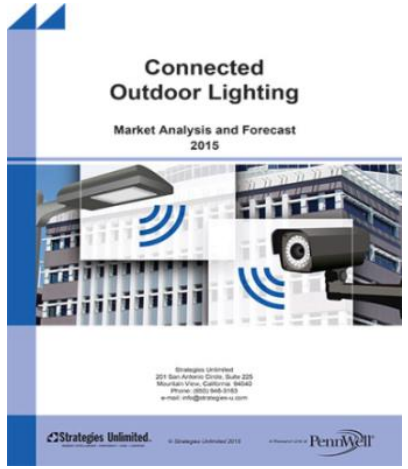


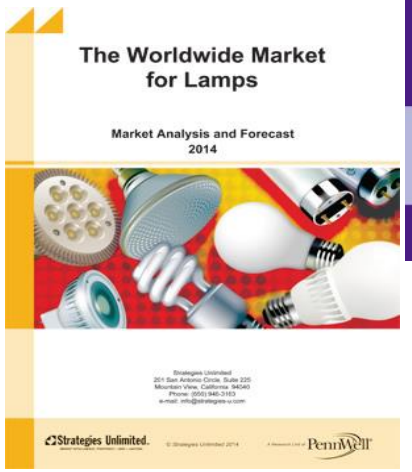










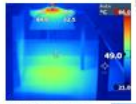


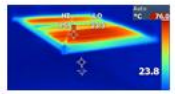
LEDs for Horticultural

Small Form Factor and Heat

- LED's small form factor provides a fixture manufacturer a degree of design freedom that they didn't have before. This enables:
  - Inter-lighting applications
  - Vertical farming applications
  - Use of secondary optics
  - Unique population patterns

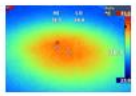
Photo Courtesy of Netled Oy





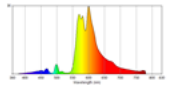
- Temperature 1000W HPS vs 400W LED grow lamp at equal distance

	Max LED	Max HPS
Fixture	75°C	84°C
Floor	31°C	63°C
Diff	44°C	21°C

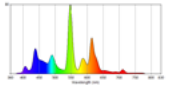


Tunable Spectrum

- Traditional light sources (HPS, MH, Fluorescent) only offer static spectrum solutions

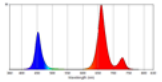


1000W HPS SPD



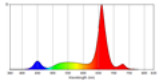
T5HO – Fluorescent SPD

- LEDs allow you to custom tune the spectrum to suit the plant's needs



Condition #1 SPD

Percent of Radiometric Power				
	Blue 400-499nm	Green 500-599nm	Red 600-699nm	Far Red 700-799nm
Condition #1	30%	0%	60%	10%
Condition #2	10%	20%	65%	5%



Condition #2 SPD

Longer Operating Life

- A major parameter in calculating ROI when deciding what type of light technology to purchase is lifetime or how often you need to replace or service the fixture.

	Average Life (hrs)
High Pressure Sodium	10K-24K (6k hours)

Time to failure

	L70B50 (hrs) (Tj=120C, If=500mA)
High Power LEDs	100K (25k hours)

Time to when flux is ≤ 70% of initial value

Disadvantages of LEDs in Horticultural

- High capital expenditure + other related incremental costs
- Optimal light recipes for specific crops & varietals still largely unproven
- PPF and PPFD of LED vs. Incumbent technologies is not equal (Especially important for plants with higher DLI)
- **Lack of Quality Standards**

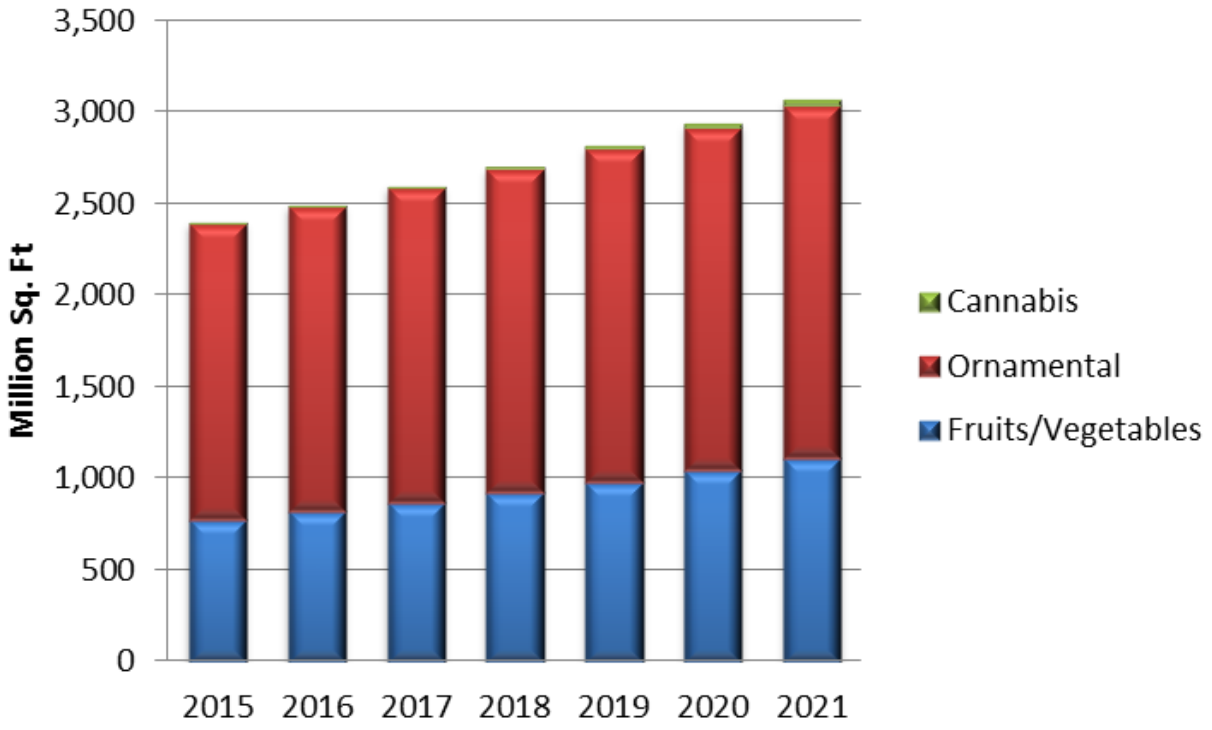
Greenhouse Lighting Market

How do You Measure the Market Cont'd?

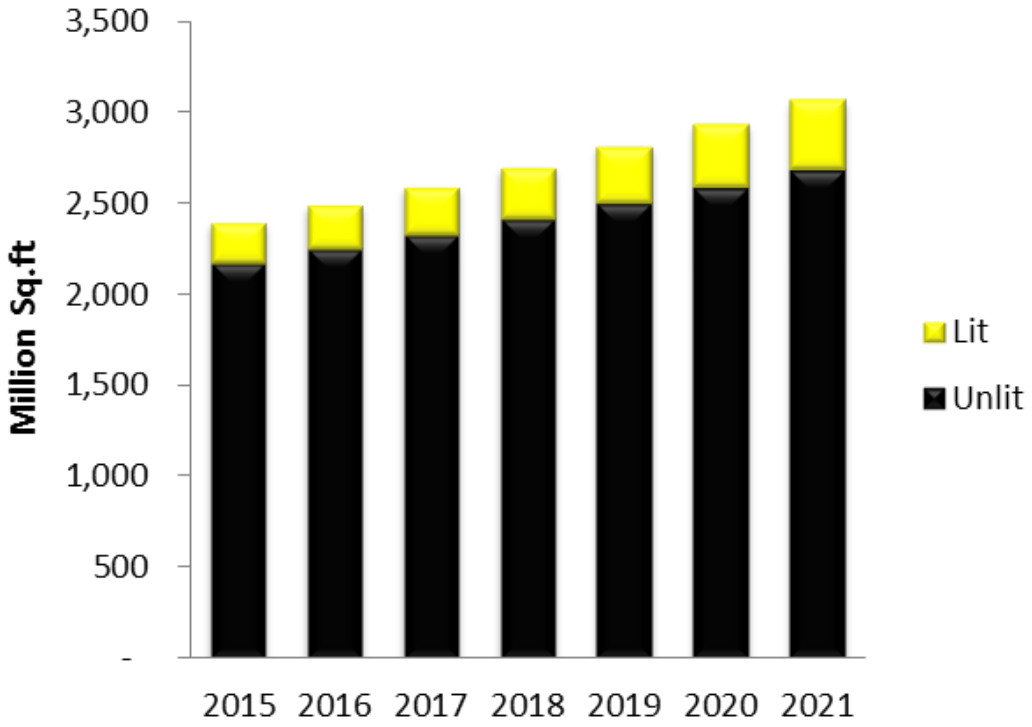
- Installed base
- What You're Measuring
  - $/Sq. Ft Light Installations by End Application
- Incumbent
  - Cost of market (Replacement Lamps and Luminaires)
- LED
  - Mostly Luminaires replacing canopy lights (For Now)
    - New form factors could have a huge impact on production!

N. A. Installed Base

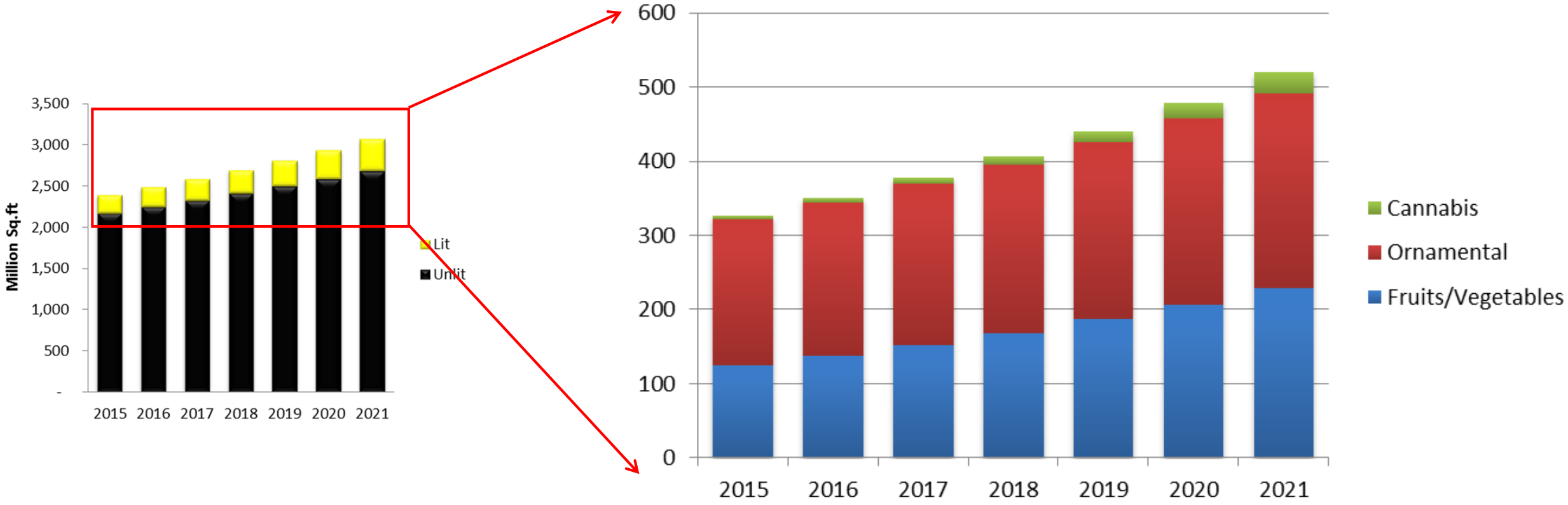
Total Sq. Ft Greenhouses



Total Sq. Ft Greenhouses Lit vs. Unlit

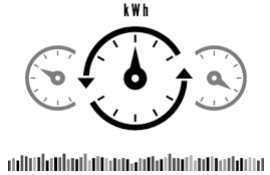


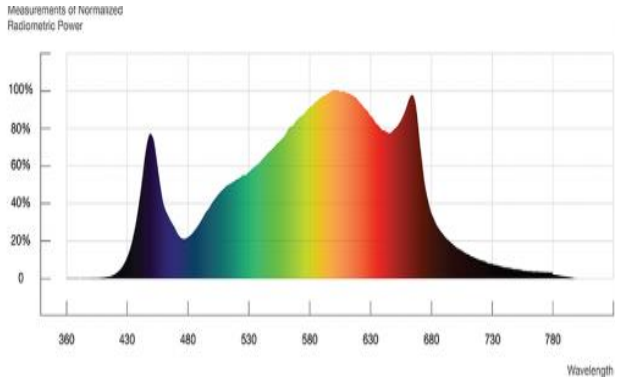
Total N.A. Illuminated Sq. Footage of Greenhouses



How do You Measure the Market Cont'd?

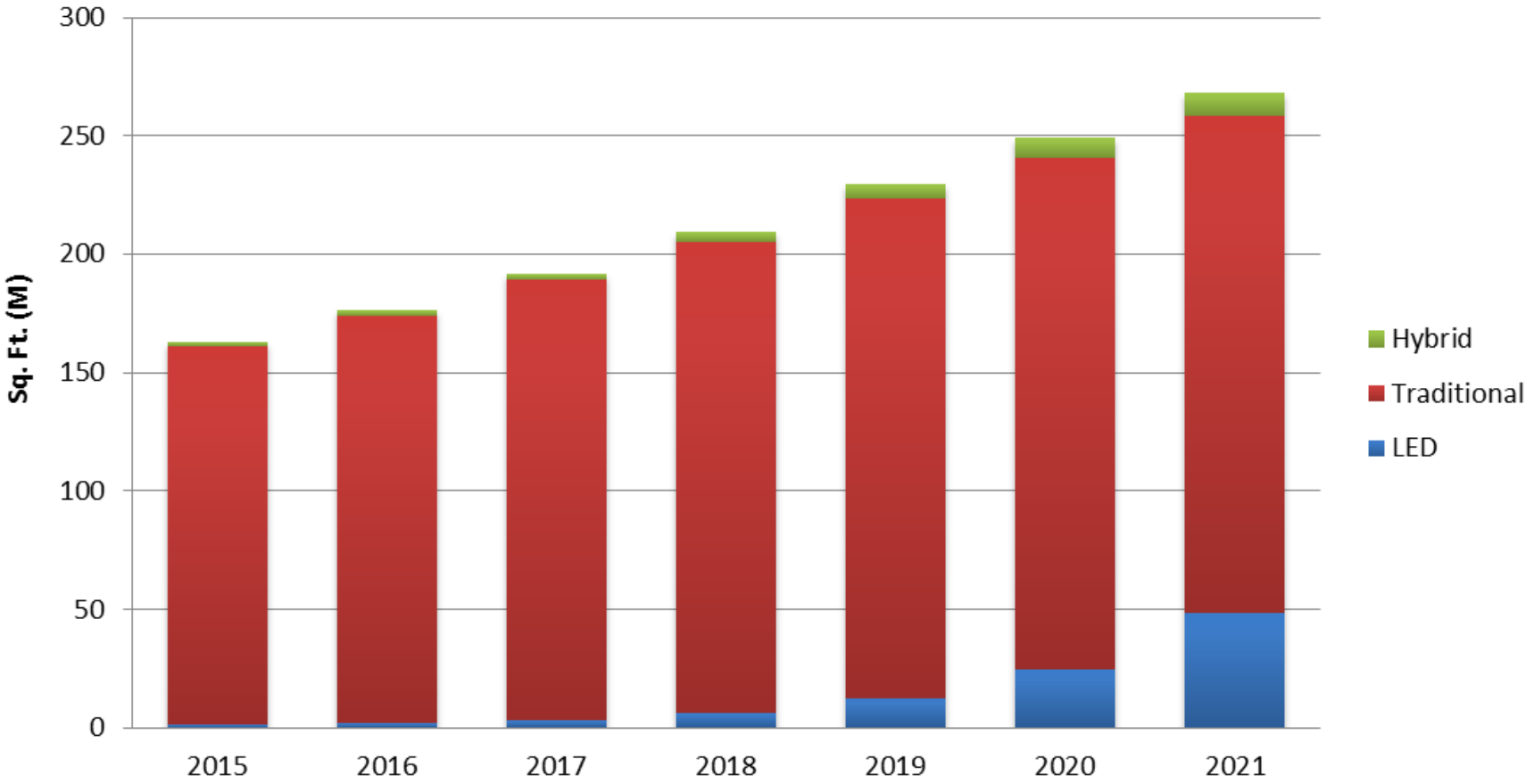
- Most likely Product
- Needs of Product
  - Costs of Production
- Lighting Qualities
  - Incumbent
  - LED
- Market Dynamics
- Geographic Dynamics
- Payback and ROI



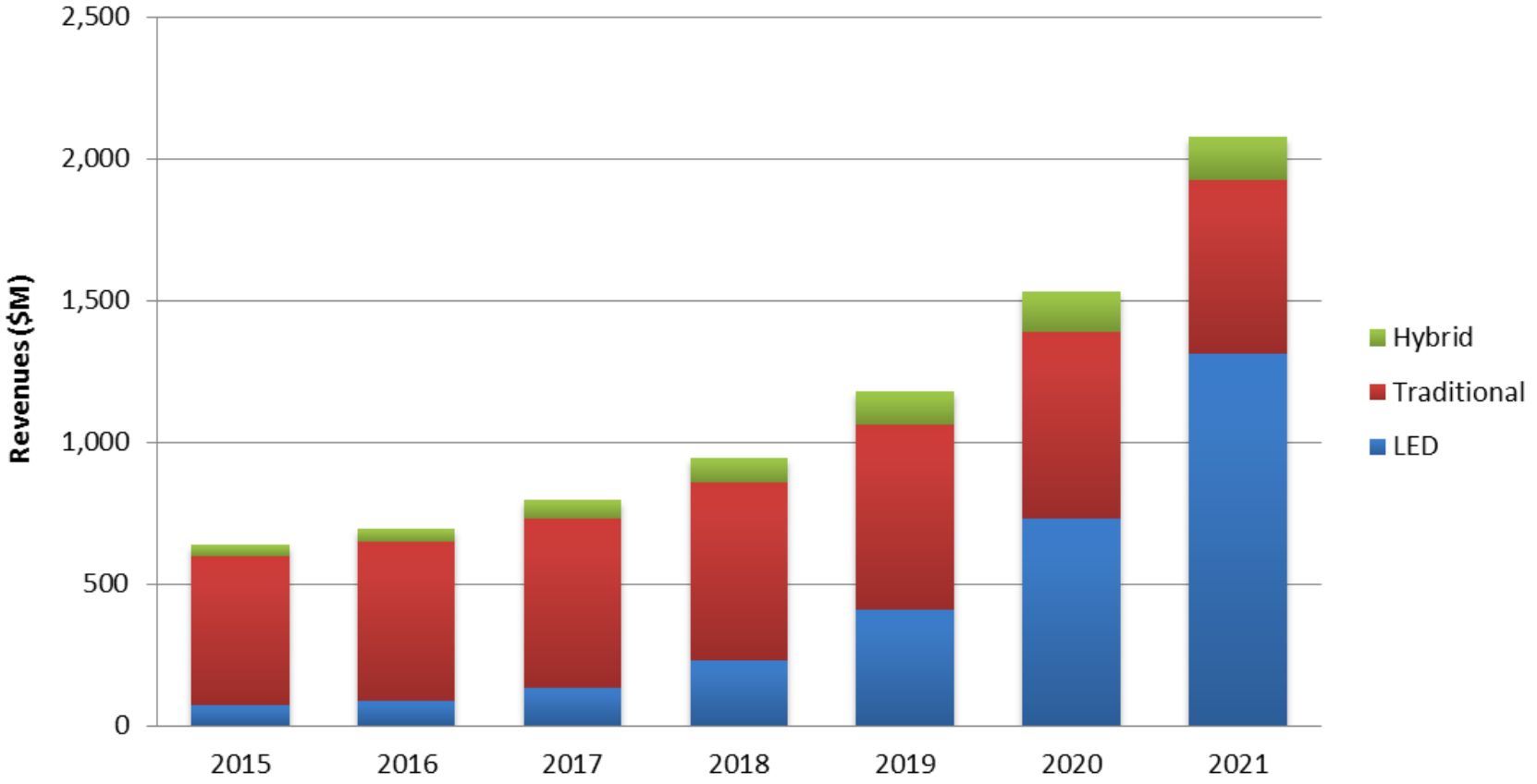


	2014	2015	2016	2017	2018	2019	2020	2021	2022
HID Fixture Watts	1000	1000	1000	1000	1000	1000	1000	1000	1000
LED Wattage Troffer	520	520	520	520	520	520	520	520	520
Saved per fixture (Watts)	480	480	480	480	480	480	480	480	480
Fixture Quantity	200	200	200	200	200	200	200	200	200
HPS Lamp Cost	30	30	30	30	30	30	30	30	30
HPS Ballast Cost	$100	$100	$100	$100	$100	$100	$100	$100	$100
LED Fixture Multiplier	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Power Saved (Watts)	96000	96000	96000	96000	96000	96000	96000	96000	96000
Daily Use (hrs)	12	12	12	12	12	12	12	12	12
Weekly Use (days)	7	7	7	7	7	7	7	7	7
Yearly Use (weeks)	52	52	52	52	52	52	52	52	52
Annual Energy Savings (kWhr)	419328	419328	419328	419328	419328	419328	419328	419328	419328
Power Cost ($/kWhr)	$ 0.11	$ 0.11	$ 0.12	$ 0.12	$ 0.13	$ 0.13	$ 0.13	$ 0.14	$ 0.14
Annual Energy Cost Savings	$ 46,797	$ 48,201	$ 49,647	$ 51,136	$ 52,670	$ 54,251	$ 55,878	$ 57,554	$ 59,281
Savings on HVAC due to LEDs	10%	10%	10%	10%	10%	10%	10%	10%	10%
HVAC Savings	$ 87,360	$ 87,360	$ 87,360	$ 87,360	$ 87,360	$ 87,360	$ 87,360	$ 87,360	$ 87,360
Capital Cost									
Cost Per LED Fixture	$ 1,300	$ 1,339	$ 1,213	$ 1,142	$ 1,074	$ 1,009	$ 948	$ 892	$ 838
Total Project Cost	$ 420,000	$ 378,000	$ 340,200	$ 319,788	$ 300,601	$ 282,565	$ 265,611	$ 249,674	$ 234,694
Labor Cost	$ 1,200	$ 1,260	$ 1,323	$ 1,389	$ 1,459	$ 1,532	$ 1,608	$ 1,689	$ 1,773
Total installation Cost	$ 421,200	$ 379,260	$ 341,523	$ 321,177	$ 302,059	$ 284,096	$ 267,219	$ 251,363	$ 236,467
LED Life (hrs)	25,000	25,000	25,000	26,250	27,563	28,941	30,388	31,907	33,502
LED Operational lifetime (yrs)	5.72	5.72	5.72	6.01	6.31	6.63	6.96	7.30	7.67
Lifetime Energy Cost Savings	$ 267,840	$ 275,875	$ 284,151	$ 307,310	$ 332,356	$ 359,443	$ 388,737	$ 420,419	$ 454,683
Maintenance Savings									
HID Life (hrs)	4,368	4,368	4,368	4,368	4,368	4,368	4,368	4,368	4,368
Repair Cost of HID Fixture	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000
Lifetime Maintenance Savings (till placement of original LED fixture)	$ 143,086.08	$ 143,086.08	$ 143,086.08	$ 150,240.38	$ 157,752.40	$ 165,640.02	$ 173,922.03	$ 182,618.13	$ 191,749.03
Yearly maintenance savings	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000
Payback years on energy alone (yrs)	9.00	7.87	6.88	6.28	5.73	5.24	4.78	4.37	3.99
Payback years on energy and HVAC alone (yrs)	3.14	2.80	2.49	2.32	2.16	2.01	1.87	1.73	1.61
Payback year on energy + Maintenance savings (yrs) no HVAC	5.87	5.18	4.58	4.22	3.89	3.58	3.30	3.04	2.81
Payback year on energy + Maintenance savings (yrs)	2.63	2.36	2.11	1.96	1.83	1.71	1.59	1.48	1.38

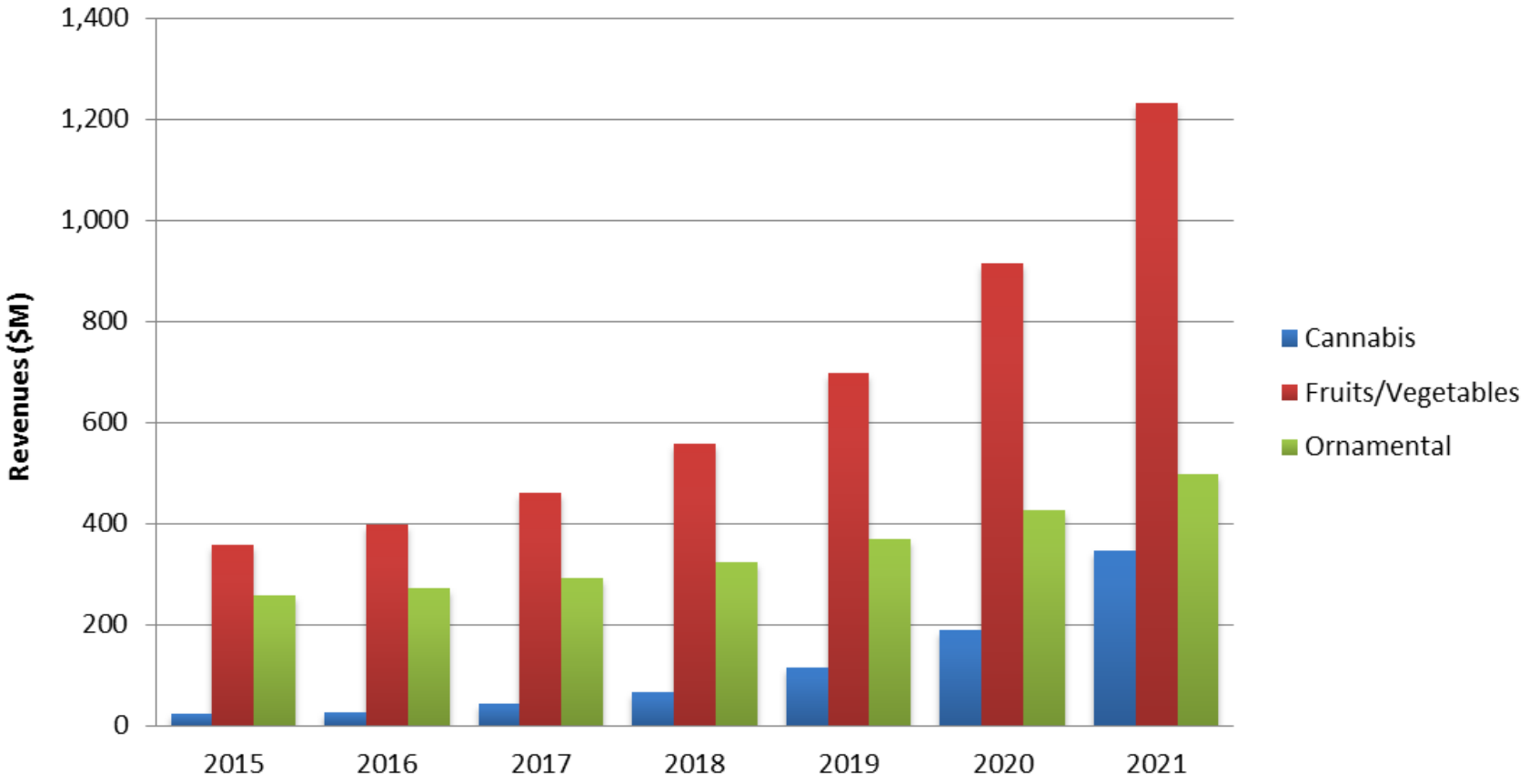
N.A. Sq. Foot area of Lighting Installations



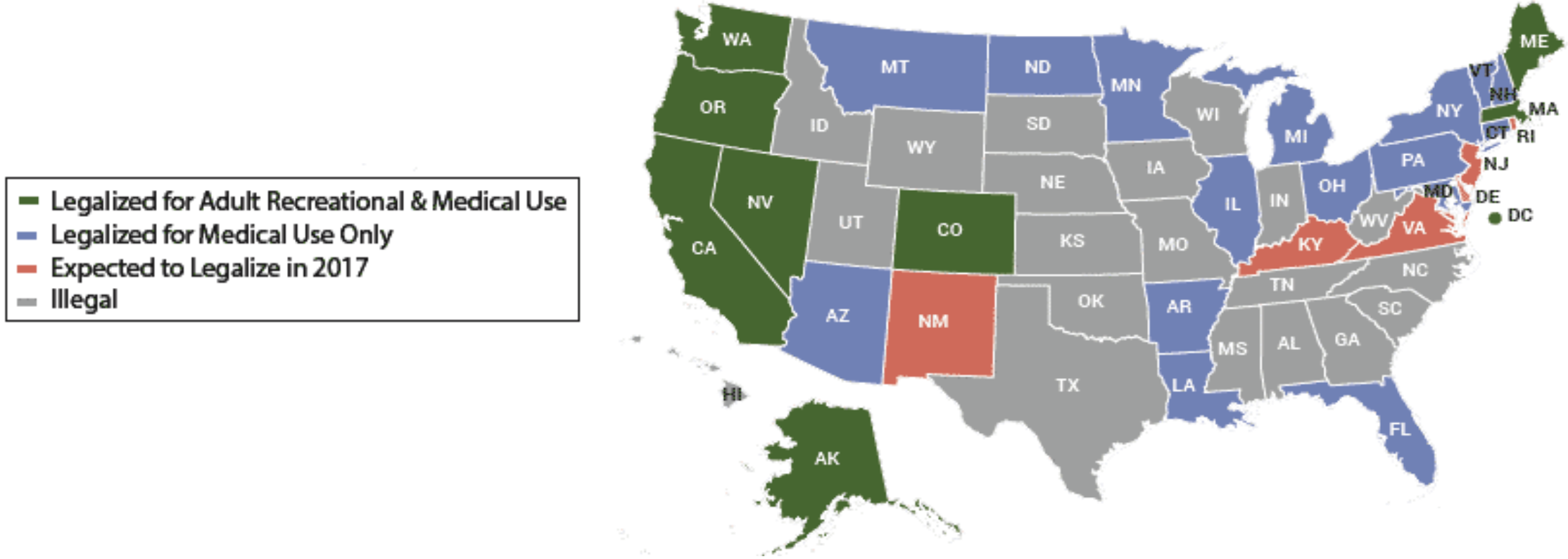
N.A. Greenhouse Lighting Market Forecast



N.A Horticultural Lighting Market by Application

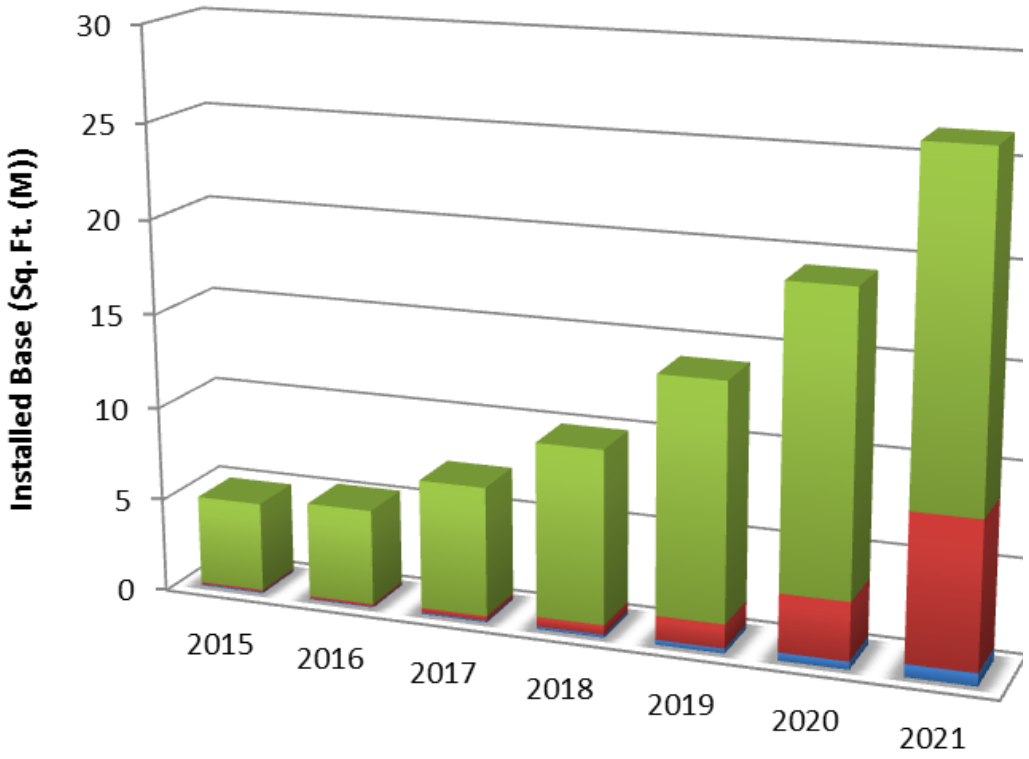


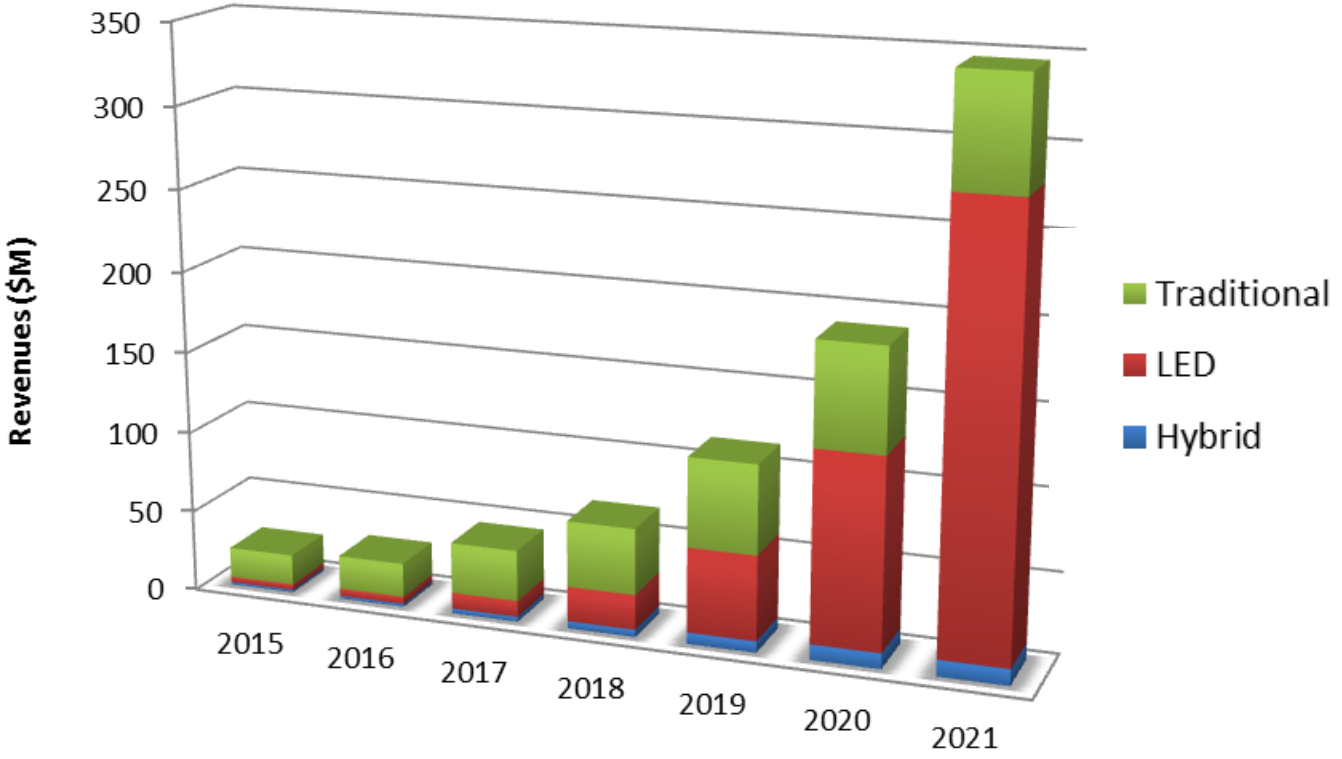
Application Focus Cannabis



Sources: Money Morning *Staff Research*

N.A. Cannabis Grow houses (Installations and Market)





Market Indicators for Growth

- 2 major indicators
  - Quality of light
  - Decreasing prices (Payback period under 3 years and ROI)
- What will speed up/slow down the market?
  - Increased Education
    - End Users
    - Manufacturers
  - Product/technology development
    - Decreased prices
    - Increased ease of use
    - Market acceptance

Standards play a major role in all of this!

PENNWELL LED & LIGHTING NETWORK

Thank You!

Philip Smallwood

Director of Research
Strategies Unlimited
Philips@pennwell.com

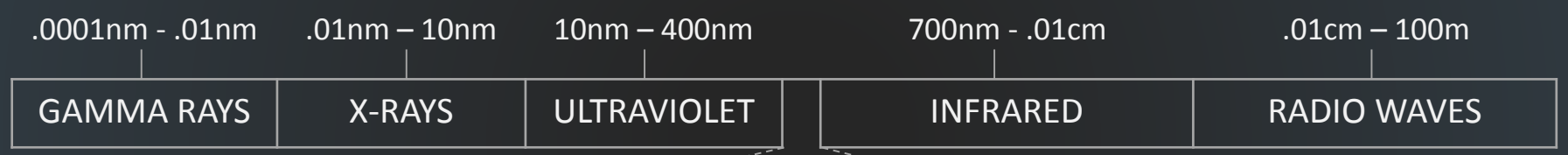
HORTICULTURE LIGHTING

NUANCES & THE NEED FOR STANDARDS

Travis Williams
Vice President of Marketing & Research, Fluence Bioengineering

PHOTOBIOLOGY

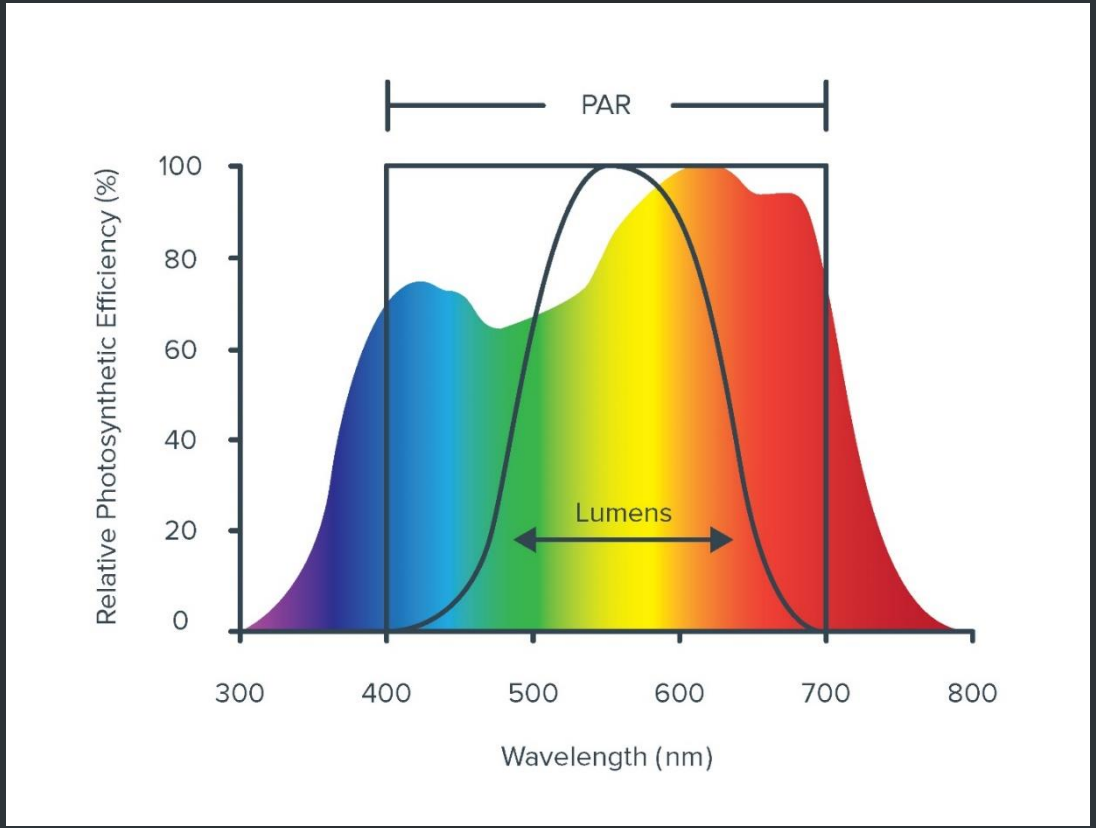
WAVE + PARTICLE (PHOTON)



PAR/VISUAL LIGHT

HORTICULTURE vs. VISION

Photopic Vision
- Lumens
- LUX /Foot Candles
- Lumens/Watt



Photobiology
- PAR
- PPF
- PPFD
- µmol/J

PHOTOBIOLOGY

PHOTOSYNTHESIS

SERIES OF LIGHT & DARK REACTIONS THAT OCCURS IN THE CHLOROPLASTS USING LIGHT ENERGY (PHOTOSYNTHETIC PHOTON FLUX) TO GENERATE CARBOHYDRATES FROM CO2 AND H20.

YIELD

PHOTOMORPHOGENESIS

LIGHT-CONTROLLED PROCESSES THAT REGULATE PLANT PHYSIOLOGICAL DEVELOPMENT OF FORM AND STRUCTURE

QUALITY

PHOTOPERIODISM

PHYSIOLOGICAL RESPONSE TO RELATIVE LENGTHS OF LIGHT AND DARK PERIODS

FLOWER/FRUIT MANIPULATION

HORTICULTURE vs. VISION

Photobiology requirements in commercial agriculture

PPF | PPFD | UNIFORMITY | SPECTRUM | EFFICACY | SIZE | PROXIMITY

The amount of light emitted by a light source. Measured in:
micromoles per second (µmol/s)

HORTICULTURE vs. VISION

Photobiology requirements in commercial agriculture

PPF | PPFD | UNIFORMITY | SPECTRUM | EFFICACY | SIZE | PROXIMITY

The amount of light reaching your canopy. Measured in:
micromoles per meter squared per second (µmol/m^2/s)

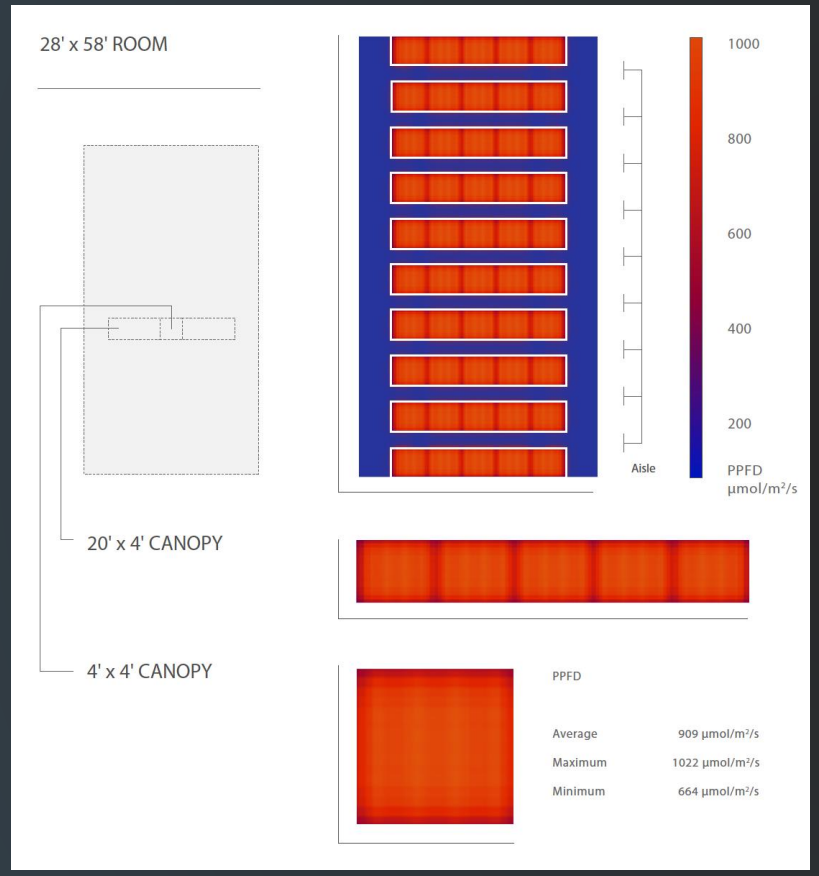
HORTICULTURE vs. VISION

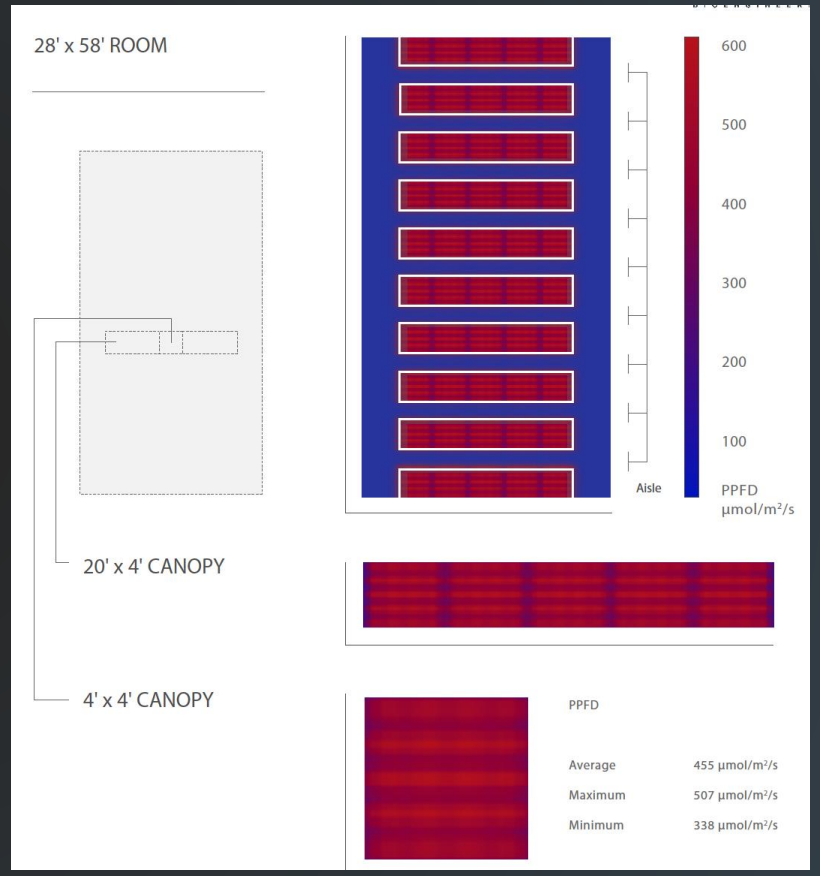
Photobiology requirements in commercial agriculture

PPF | PPFD | UNIFORMITY | SPECTRUM | EFFICACY | SIZE | PROXIMITY

The average, maximum and minimum amount of ppfd. Measured with:
a PAR map

HORTICULTURE vs. VISION





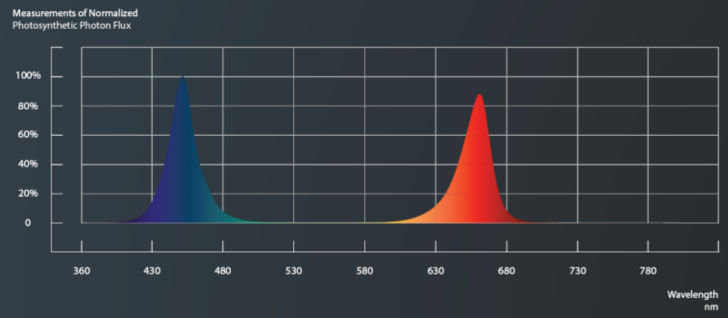
HORTICULTURE vs. VISION

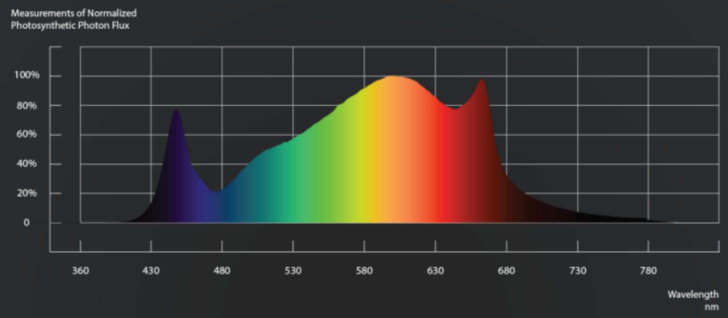
Photobiology requirements in commercial agriculture

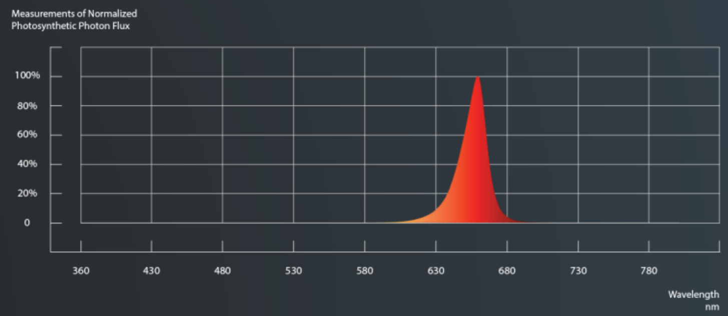
PPF | PPFD | UNIFORMITY | SPECTRUM | EFFICACY | SIZE | PROXIMITY

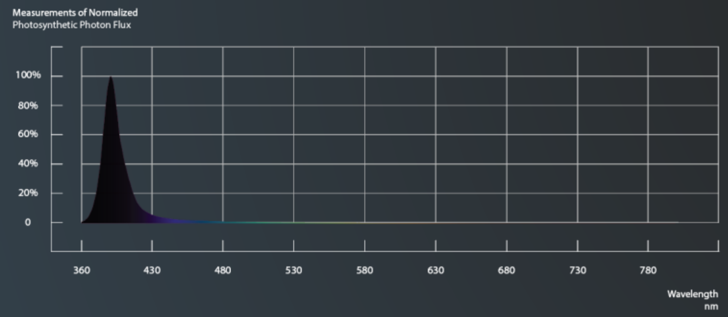
The proportions of different wavelengths. Measured with:
a spectral power distribution chart

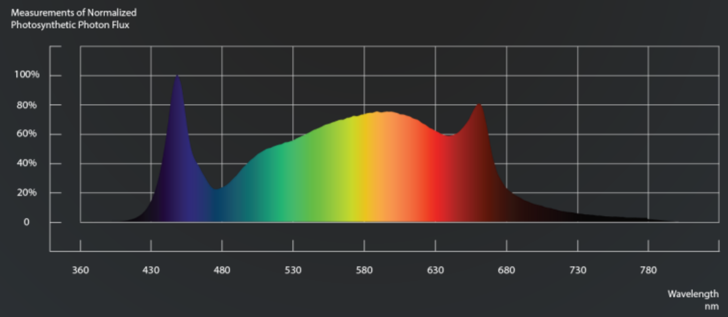
HORTICULTURE vs. VISION

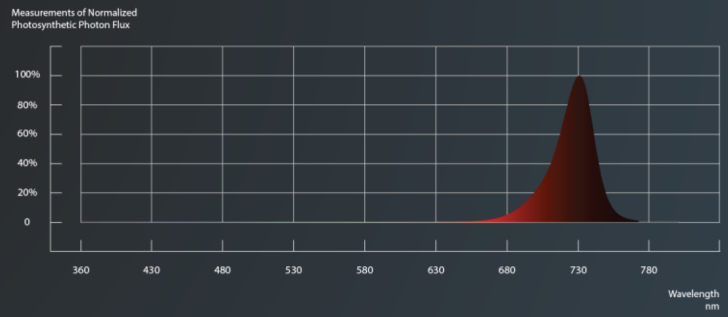








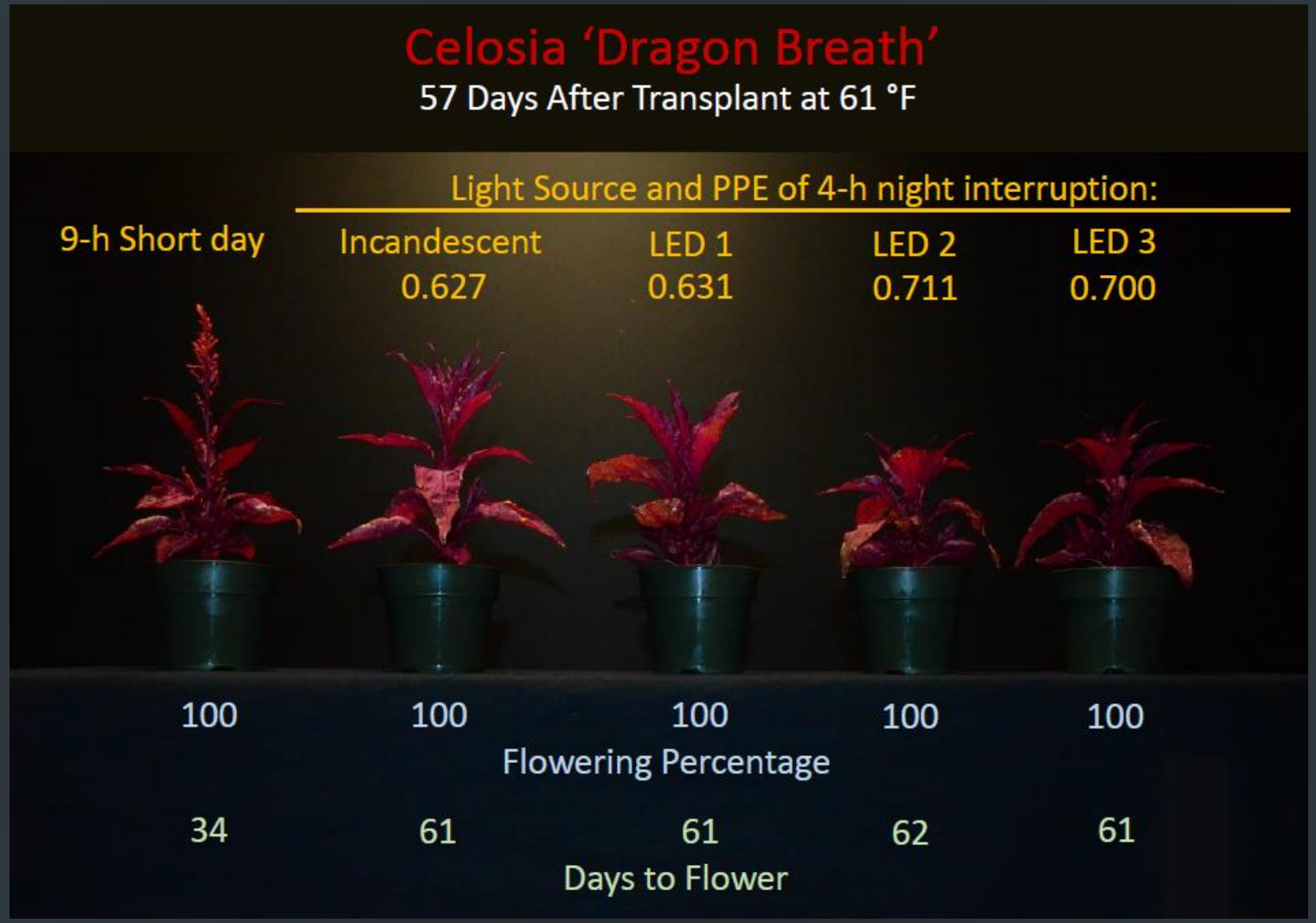


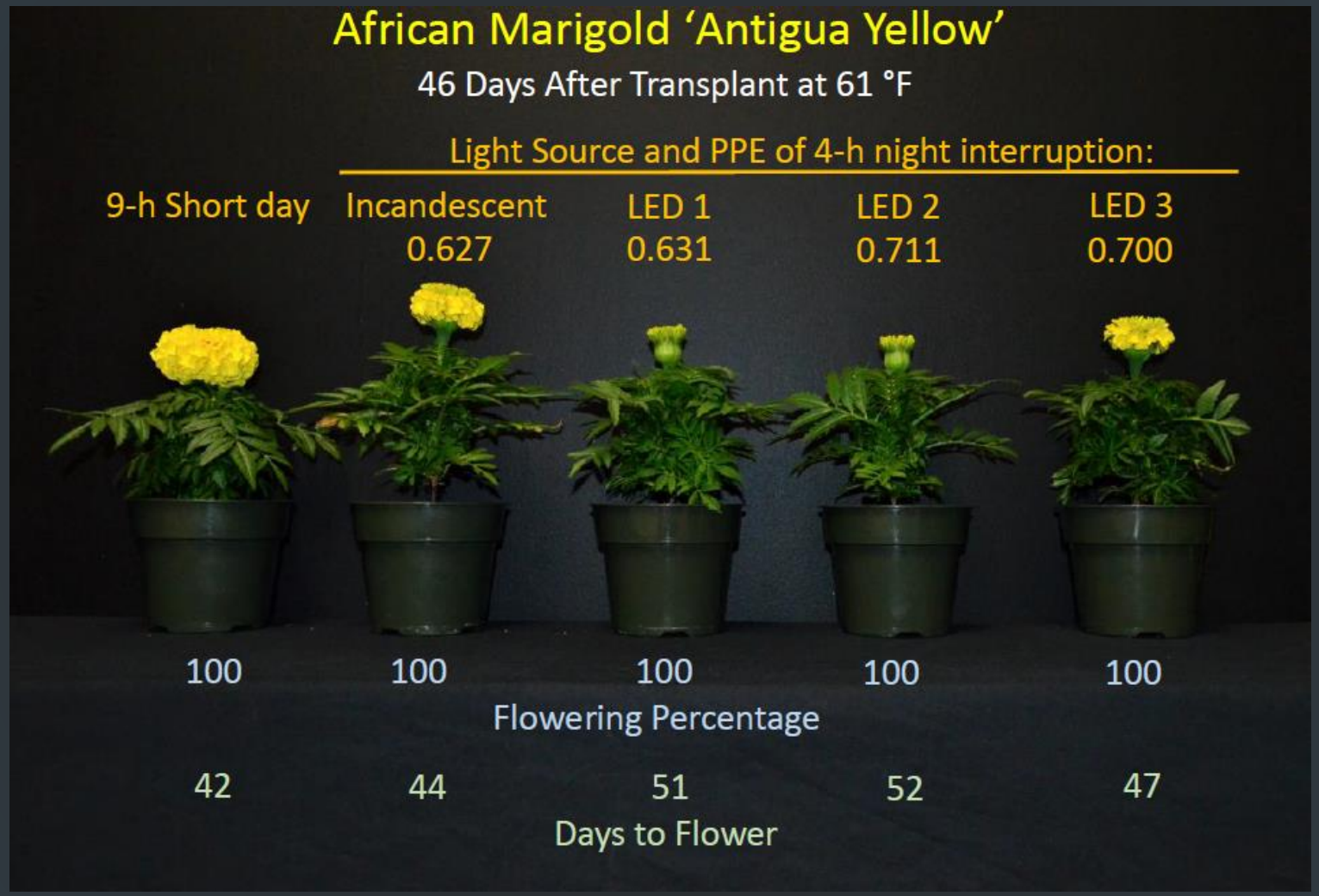



Petunia 'Classic Purple Wave'
57 Days After Transplant at 61 °F
Light Source and PPE of 4-h night interruption:
9-h Short day
Incandescent
0.627
LED 1
0.631
LED 2
0.711
LED 3
0.700
-
92
58
92
-
Flowering Percentage
-
56
61
58
-
Days to Flower

Celosia 'Dragon Breath'

57 Days After Transplant at 61 °F




African Marigold 'Antigua Yellow'
46 Days After Transplant at 61 °F
Light Source and PPE of 4-h night interruption:
9-h Short day
Incandescent
0.627
LED 1
0.631
LED 2
0.711
LED 3
0.700
100
100
100
100
100
Flowering Percentage
42
44
51
52
47
Days to Flower

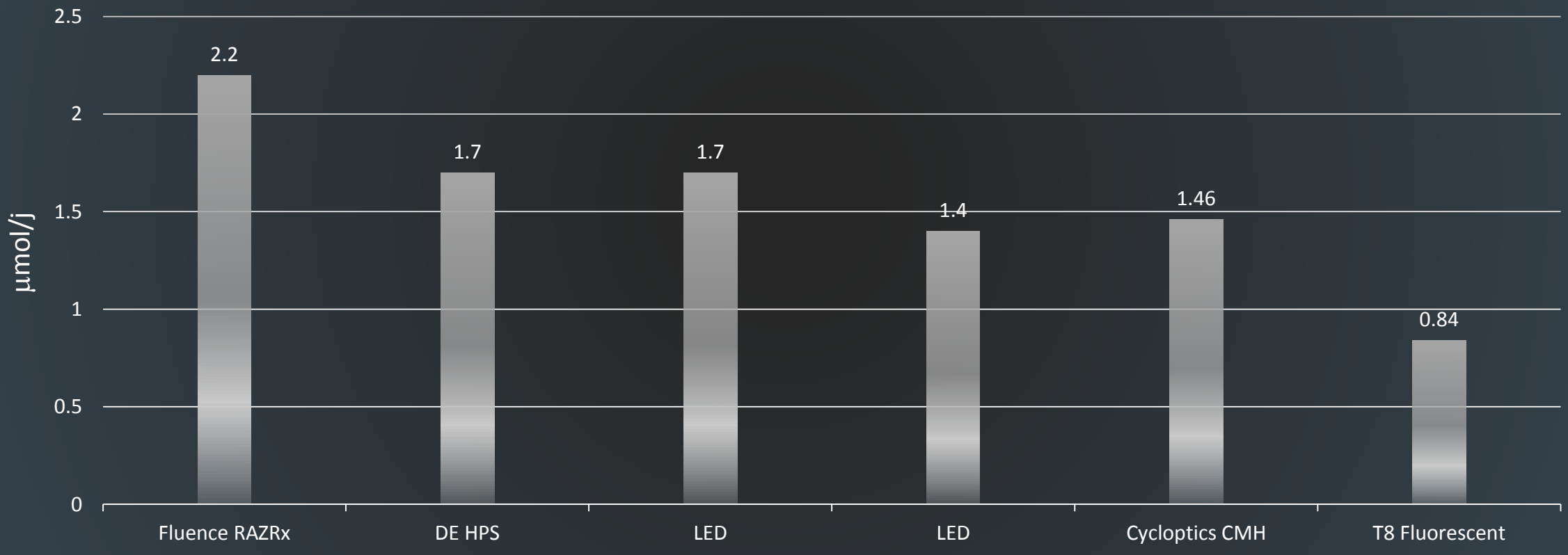
HORTICULTURE vs. VISION

Photobiology requirements in commercial agriculture

PPF | PPFD | UNIFORMITY | SPECTRUM | EFFICACY | SIZE | PROXIMITY

How energy efficient a light fixture is at converting electrons into photons. Measured in: Micromoles per joule (µmol/J)

EFFICACY



*DATA FROM PEER REVIEWED JOURNAL – DR. BUGBEE

HORTICULTURE vs. VISION

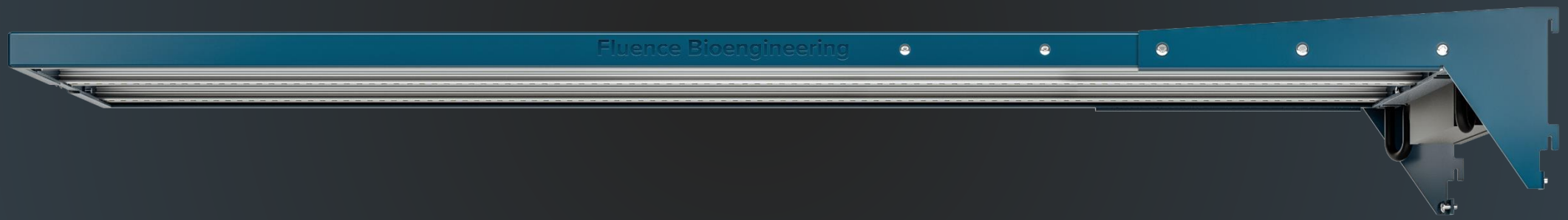
Photobiology requirements in commercial agriculture

PPF | PPFD | UNIFORMITY | SPECTRUM | EFFICACY | SIZE | PROXIMITY

How much space does your lighting system require? Measured in:
inches, centimeters, millimeters, etc.

HORTICULTURE vs. VISION

1.2”



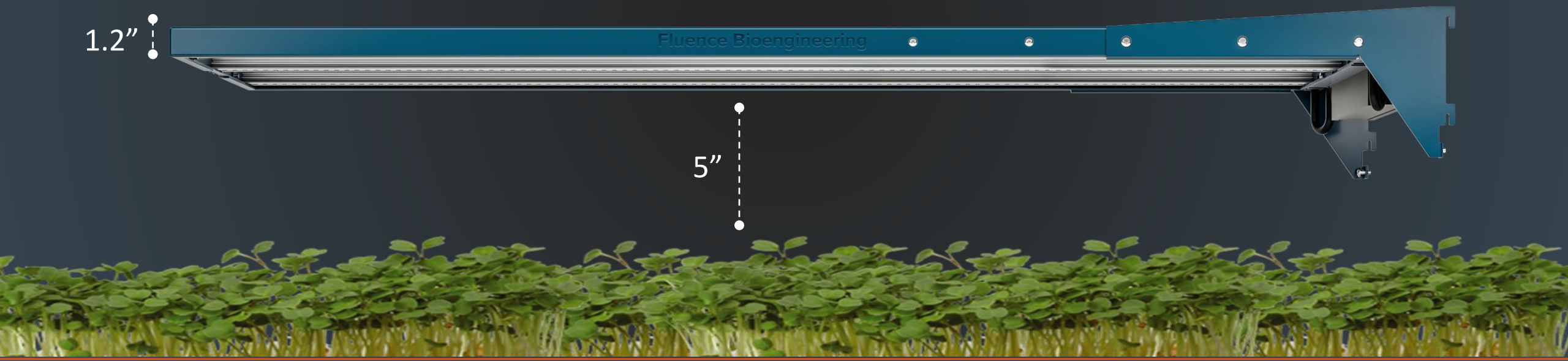
HORTICULTURE vs. VISION

Photobiology requirements in commercial agriculture

PPF | PPFD | UNIFORMITY | SPECTRUM | EFFICACY | SIZE | PROXIMITY

Space requirements from light to canopy? Measured in:
inches, feet, centimeters, millimeters, etc.

HORTICULTURE vs. VISION



HORTICULTURE vs. VISION

Factors to consider when designing or deploying a horticulture lighting solution

RH | TEMPERATURE | RADIANT HEAT | CO2 | IRRIGATION | & SO MUCH MORE

LIGHTING TECHNOLOGIES

A quick look at what's in use

LED | CMH | HPS | FLUORESCENT | PLASMA | & SO MUCH MORE

SPECTRAL POWER DISTRIBUTION CHART
High Pressure Sodium

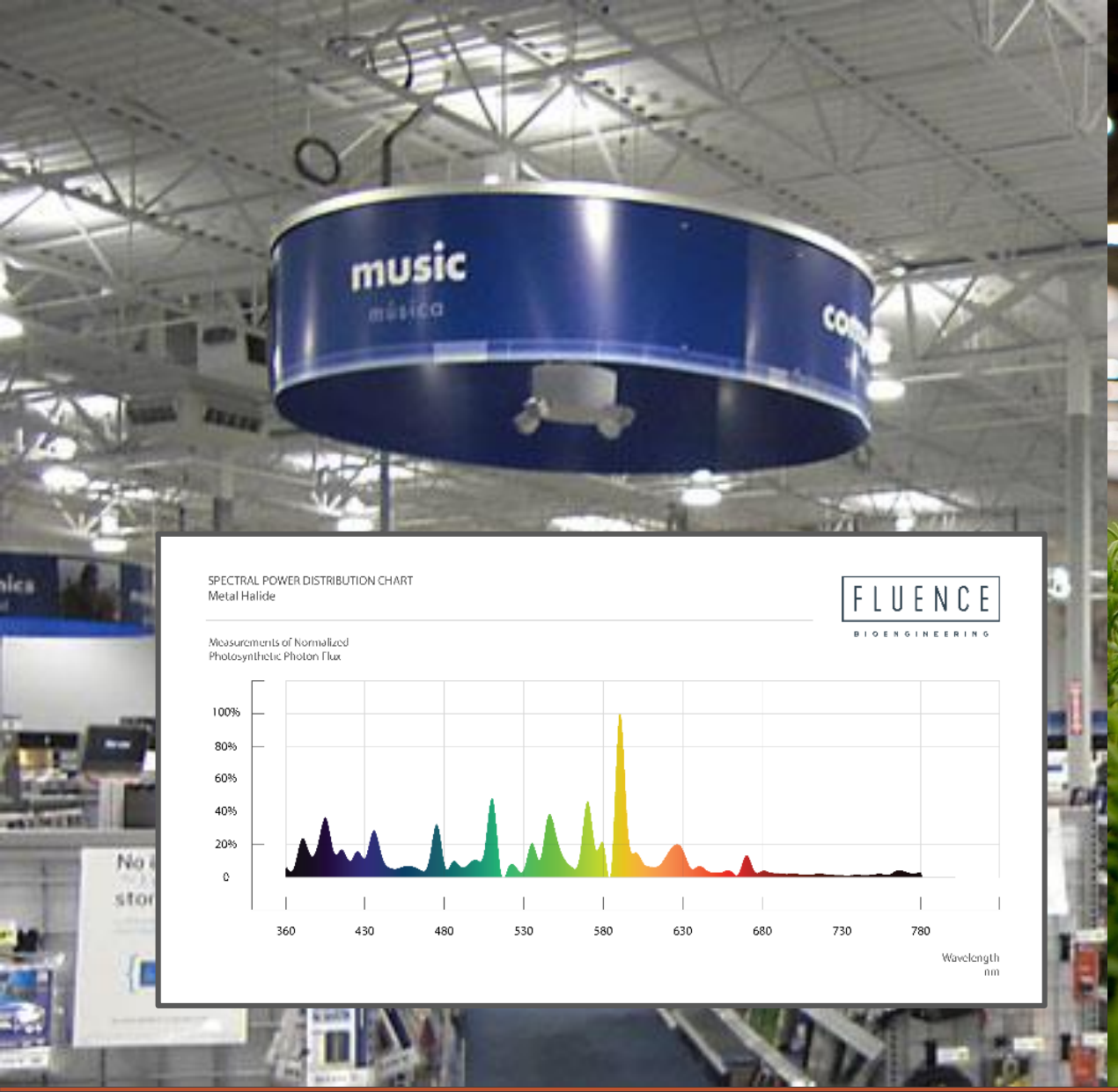
FLUENCE
BIOENGINEERING

Measurements of Normalized
Photosynthetic Photon Flux

SPECTRAL POWER DISTRIBUTION CHART
PhysioSpec Indoor™

FLUENCE
BIOENGINEERING

Measurements of Normalized
Photosynthetic Photon Flux



SPECTRAL POWER DISTRIBUTION CHART
Metal Halide

FLUENCE
BIOENGINEERING

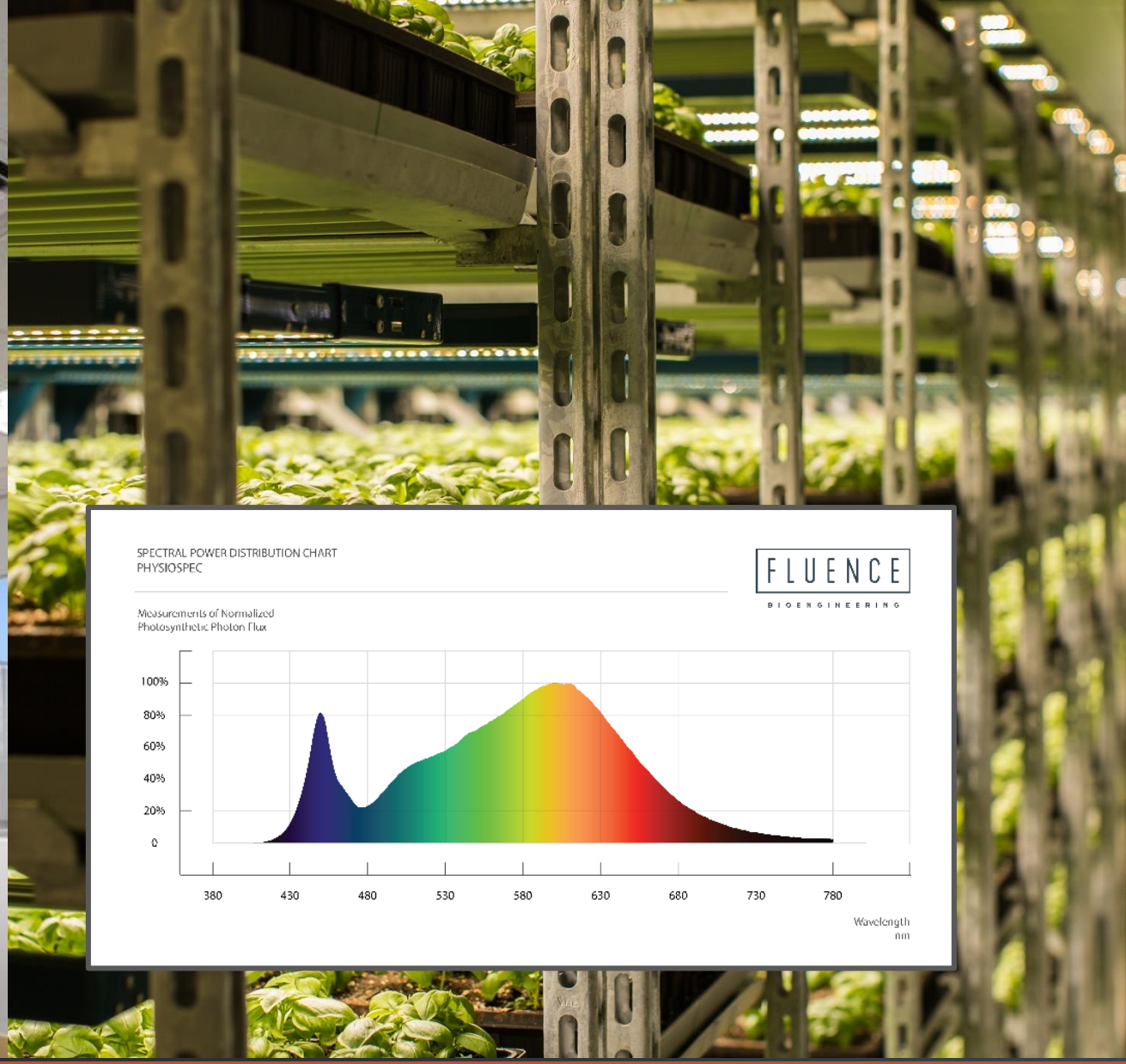
Measurements of Normalized
Photosynthetic Photon Flux

SPECTRAL POWER DISTRIBUTION CHART
PhysioSpec Greenhouse ™

FLUENCE
BIOENGINEERING

Measurements of Normalized
Photosynthetic Photon Flux


SPECTRAL POWER DISTRIBUTION CHART
T5 Fluorescent
FLUENCE
BIOENGINEERING
Measurements of Normalized
Photosynthetic Photon Flux
100%
80%
60%
40%
20%
0
360
430
480
530
580
630
680
730
780
Wavelength
nm


SPECTRAL POWER DISTRIBUTION CHART
PHYSIOSPEC
FLUENCE
BIOENGINEERING
Measurements of Normalized
Photosynthetic Photon Flux
100%
80%
60%
40%
20%
0
380
430
480
530
580
630
680
730
780
Wavelength
nm

LIGHTING TECHNOLOGIES

Today and tomorrow

GREENHOUSE TOP LIGHT | GREENHOUSE INTRACANOPY | GREENHOUSE VERTICAL | VERTICAL FARMING | GROWTH CHAMBERS | & SO MUCH MORE

DLC STAKEHOLDER MEETING

FLUENCE

JULY 2017

DLC STAKEHOLDER MEETING

FLUENCE

JULY 2017

DLC STAKEHOLDER MEETING

FLUENCE

JULY 2017

FUTURE

EMPOWERED BY TECHNOLOGY

LED efficiency gains

Thermal management

Automation & big data

FUTURE

EMPOWERED BY SCIENCE

Custom spectra

Environmental optimizations

Genetic optimizations

OPPORTUNITIES

SAVING ENERGY *AND/OR* MAKING MONEY

Maximize yield per cubic foot

Minimize operating cost/pound

Augment pricing power
(quality/consistency/forecast)

FOR NEXT TIME

NOW THAT THE BASICS ARE COVERED

Degradation
Maintenance, loss, inconsistency

Rohs
Avoiding mercury and other harmful contaminants

CU
Don’t waste photons

SUMMARY

Plants use light might much differently than humans

Growers/KDMs are largely uneducated when it comes to photobiology

There are myriad factors for CEA. No one-size fits all.

Horticulture lighting *should be* revenue-generating, not cost-saving.

WE (ALL OF US) WILL BENEFIT FROM INDUSTRY STANDARDS.

What's Growing on in Oregon

Evergreen
Consulting Group

Grow Light Options

Utility perspective from the front lines

Legacy Technologies

Baseline or industry standard

1,000 watt High Pressure Sodium, single ended lamp (one socket)

INDUSTRY RULE OF THUMB – 16 S.F. per grow

Provides approximately 700 to 800 PPFD µmol/m2 S

Step up from a Singled Ended HPS

1,000 watt High Pressure Sodium
Double ended lamp

Provides approximately 800 to 1,000 PPFD µmol/m2 S

- *Single Ended (SE). Mogul base The arc tube connects to the base of the bulb with a metal frame wire holding it by each end*
- *Double Ended (DE). Connects on each end at the lamp much like a fluorescent tube*
- *Because of the support and shapes, the DE is much thinner than SE which improves optical properties. Exposing the arc tube to the bulb without any metal framing in the way, increases light delivery. The symmetry of the DE bulbs allows you to create an even spread of light.*
- *Hours: It would appear that SE bulbs last longer than DE bulbs but in reality, you need to change the SE bulb every 6,000 hours and every DE bulb every 10,000 hours to maintain optical properties*
- *Efficiency: SE bulbs are vacuum, DE bulbs are full of nitrogen gas. The gas allows the bulb to operate at higher temperatures, which increases it's efficiency. But, any air movement (fans) can cool the lamp decreasing efficiency.*

Hightimes.comBy Sirius J May 24, 2016

Induction

Race track style
Load 440 watts
Life of lamp 100,000 hours

Provides approximately 300 to 400 PPFD µmol/m2 S

Light Emitting Ceramic (LEC)

Ceramic Metal Halide (CMH)

2/315 watt CMH lamps

Load 630 watts/240 volts @ 100%

Provides approximately 700 to 800 PPFD µmol/m2 S

One 315 watt lamp is ½

Light Emitting Plasma

1/270 watt Plasma

Load 270 watts/240 volts @ 100%

Life of lamp – 50,000

Provides approximately to 200 to 300 PPFD µmol/m2 S

Tube LED (TLED)

54 watt T5 HO fluorescent baseline

28 watt T5TLED

Works off existing fluorescent ballast

Life of lamp – 50,000 hours

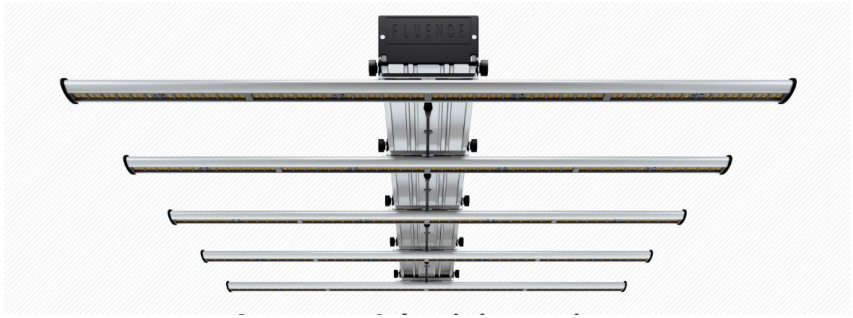
Provides approximately to 500 to 600 PPFD µmol/m2 S
(8-lamp luminaire)

Hybrid

LED (dimmable, tunable)

Average around 600 watts

Life of LED: 50,000 hours @ 70% output

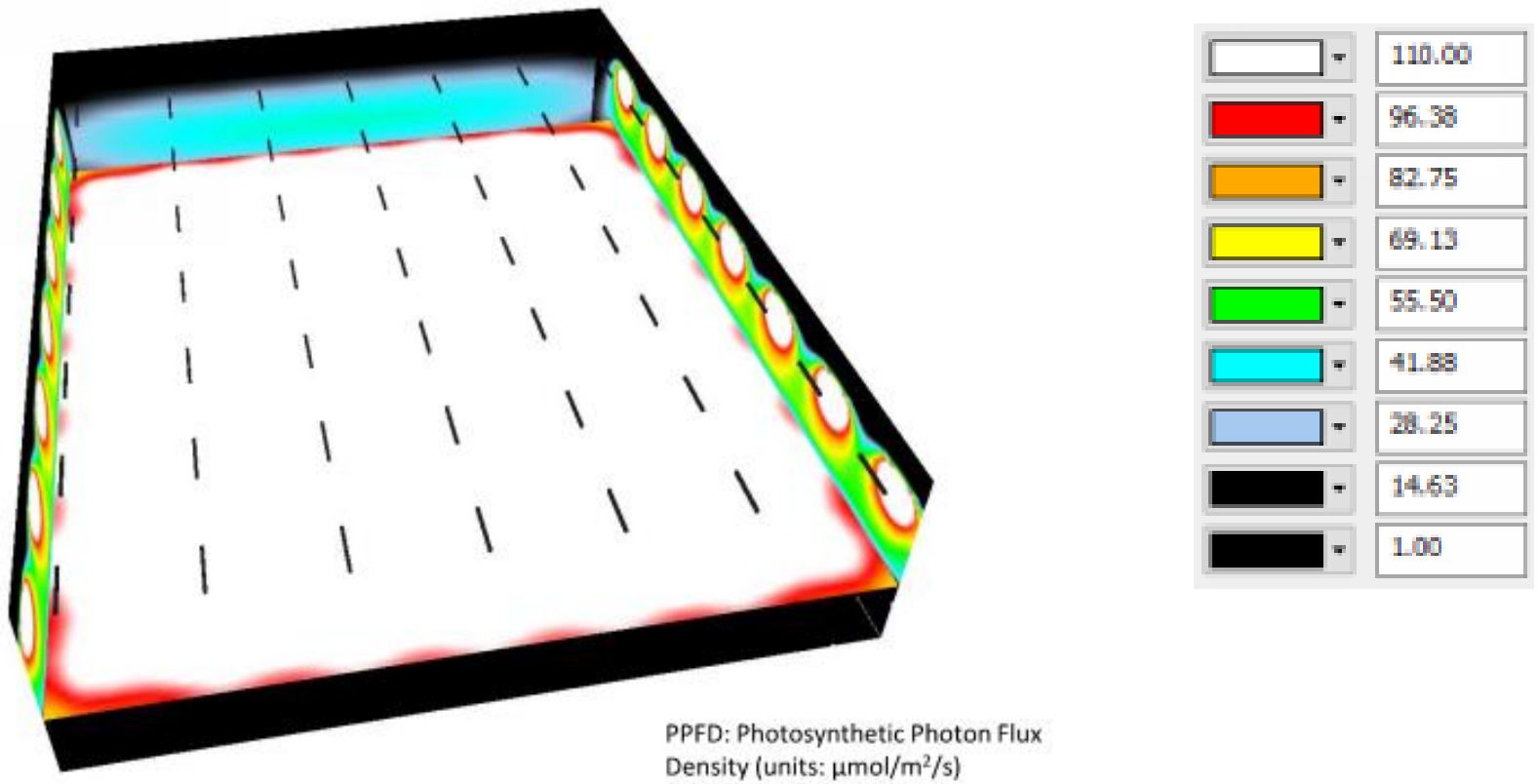


Some provide approximately 1,000 to 1,200 PPFD µmol/m2 S

What manufacturers should provide

- Height above the canopy: 7’ 4”
- PPFD: 138 (average), 166 (max), 75 (min)
- Light loss Factor: 0.99

PPFD distribution at 7’ 4” from the fixtures



PPFD: Photosynthetic Photon Flux Density (units: µmol/m²/s)

Reducing your operational costs

Time is money – cent's per kWh

Indoor

Clone - 18 to 24 hours 7 days per week (8,760)

Vegetative stage - 18 hours 7 days per week (6,570)

Flowering stage - 12 hours 7 days per week (4,380)

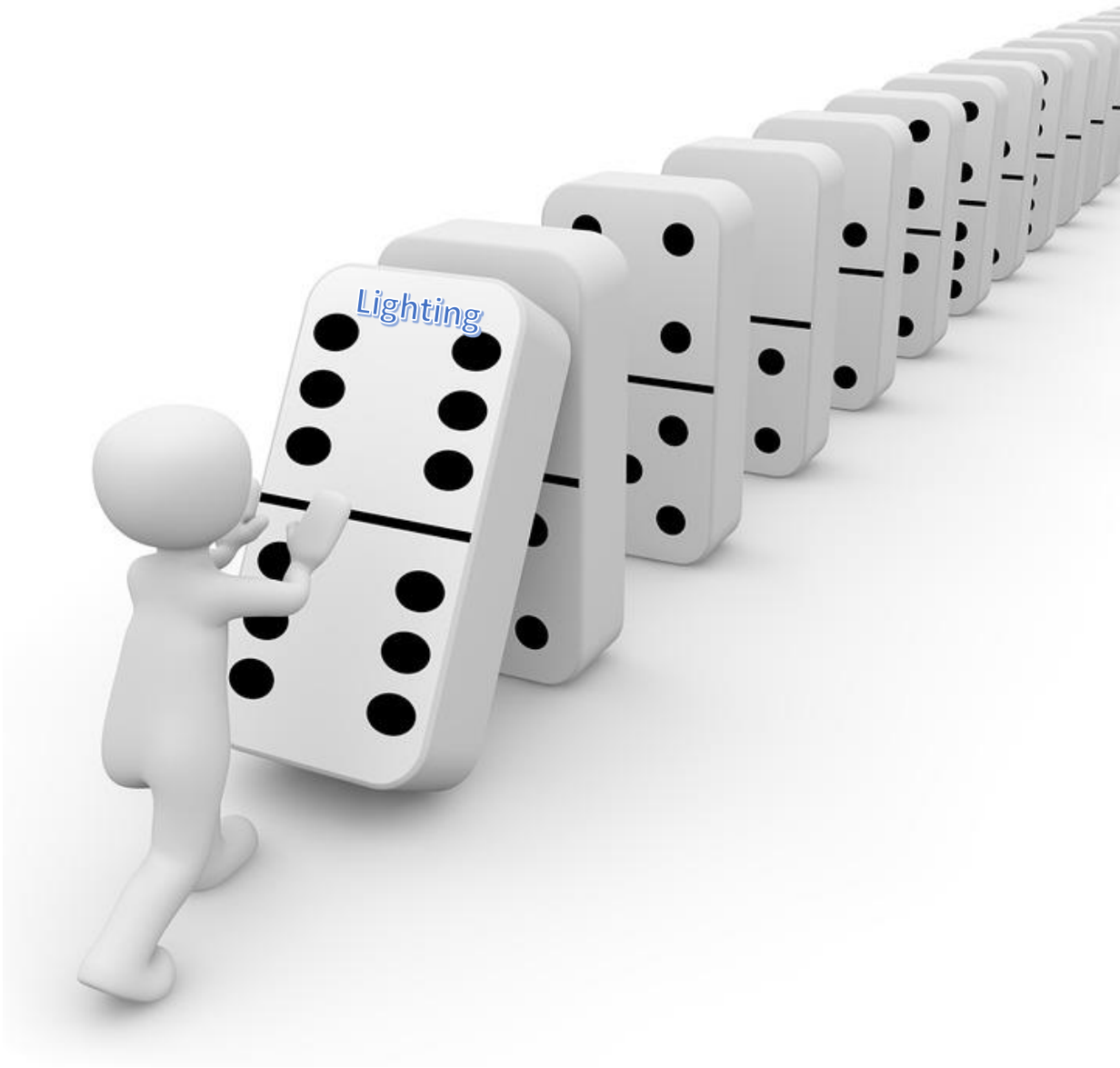
Green house

2,118 annual hours for supplemental electric lighting

Lighting is the largest load in an indoor grow operation

Less lighting load means…

- *Less HVAC load*
- *Less fan load*
- *Less electrical service costs*
- *Less insulation*
- *And more*
- *The gift that keeps on giving*



Virtual case study

3,500 S.F. canopy grow operation

Flower room

218, 1,000 watt HPS virtual grow lights (3,500/16 SF)

$200 ea.

4,380 annual hours

218, 640 watt LED grow lights $1,200 ea.

Estimated Annual Energy Savings	429,654	kWh
Estimated Annual Cost Savings	$ 44,224	per year
Estimated Energy Trust of Oregon Incentive	$ 107,414	
Additional Estimated Incentive, if applicable	$ -	
Estimated Installation Cost	$ 218,000	

Based on your proposed retrofit and estimated installation cost, we show the following financial analysis:

Estimated Installation Cost	$ 218,000
minus Energy Trust of Oregon incentive	$ (107,414)
Net Installation Cost	$ 110,586
Energy Savings Payback (in years)	2.5
% of installed cost paid for by incentives	49%
Rate of Return	40%

Estimated cost for every year the project is delayed	$ 44,224	**PROFIT after 2.5 years!!**

This project requires a pre-installation inspection.

This is an estimate only, as actual savings and incentives will vary based on final installed measures and costs, actual area operating hours, energy rates and building usage.

Green Project Box: ***(Estimate for informational purposes only. The carbon footprint from electricity generation is calculated from a regional average, which may be different than the national average.)***

This proposed project could offset approximately **204** tons of CO2 generated by fossil fuels, equal to taking more than **29** cars off the road.

QPL lists for Horticulture

- Needs to be cognizant of growers methodology, designs and procedures that produce high yields
- Utilities: Should there be a list or should there be specifications to meet?

Thank you

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Thank You!

Irina Rasputnis

DLC

Philip Smallwood

Strategies Unlimited

Travis Williams

Fluence Bioengineering

Doug Oppedal

Evergreen Consulting