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Retrofitting Older Growth Chambers to Improve PPF, Electrical Efficiency and Uniformity

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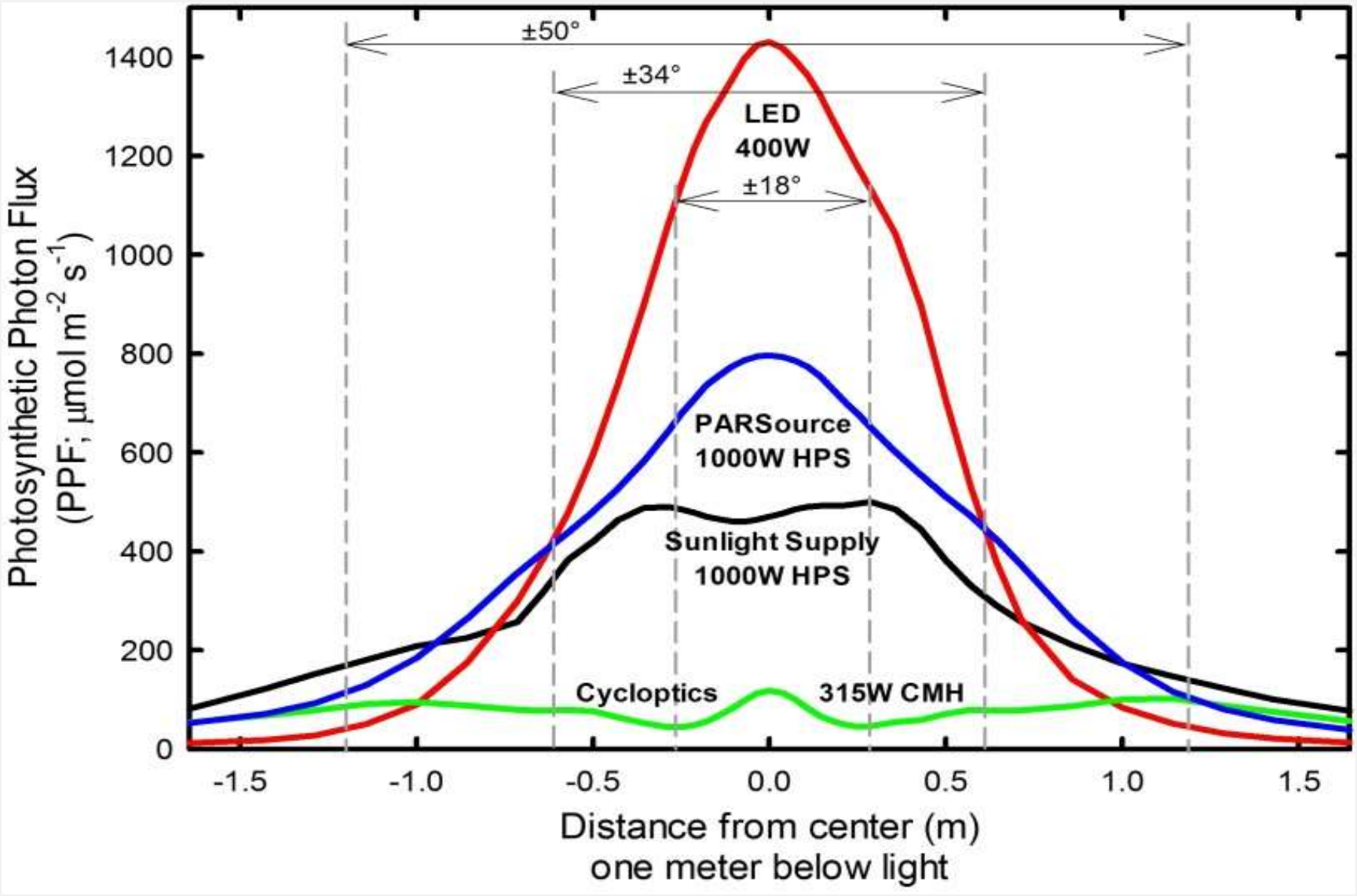
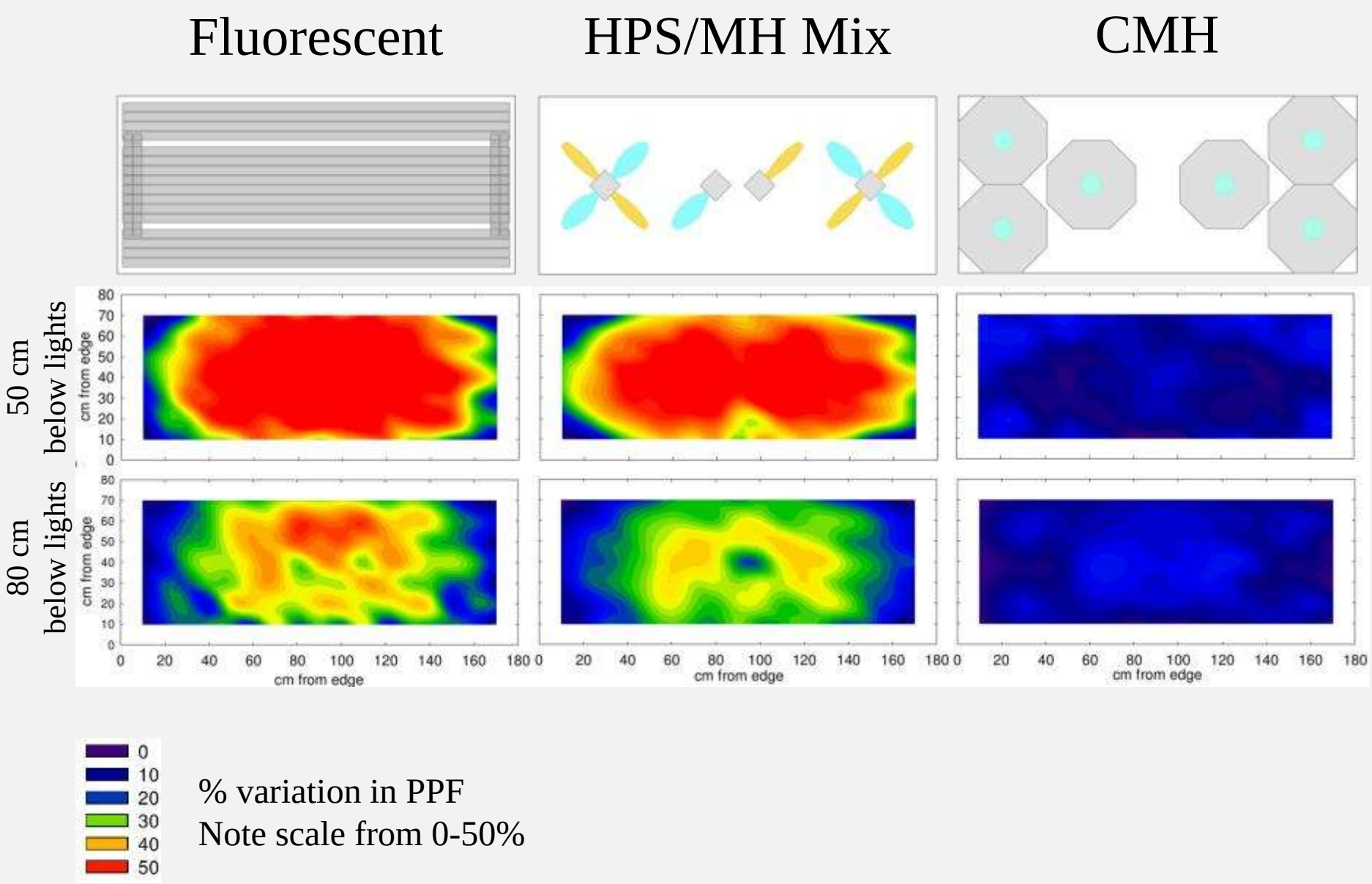
DEPARTMENT OF PLANTS, SOILS, & CLIMATE

USU Retrofit: Conviron E15 Growth Chamber

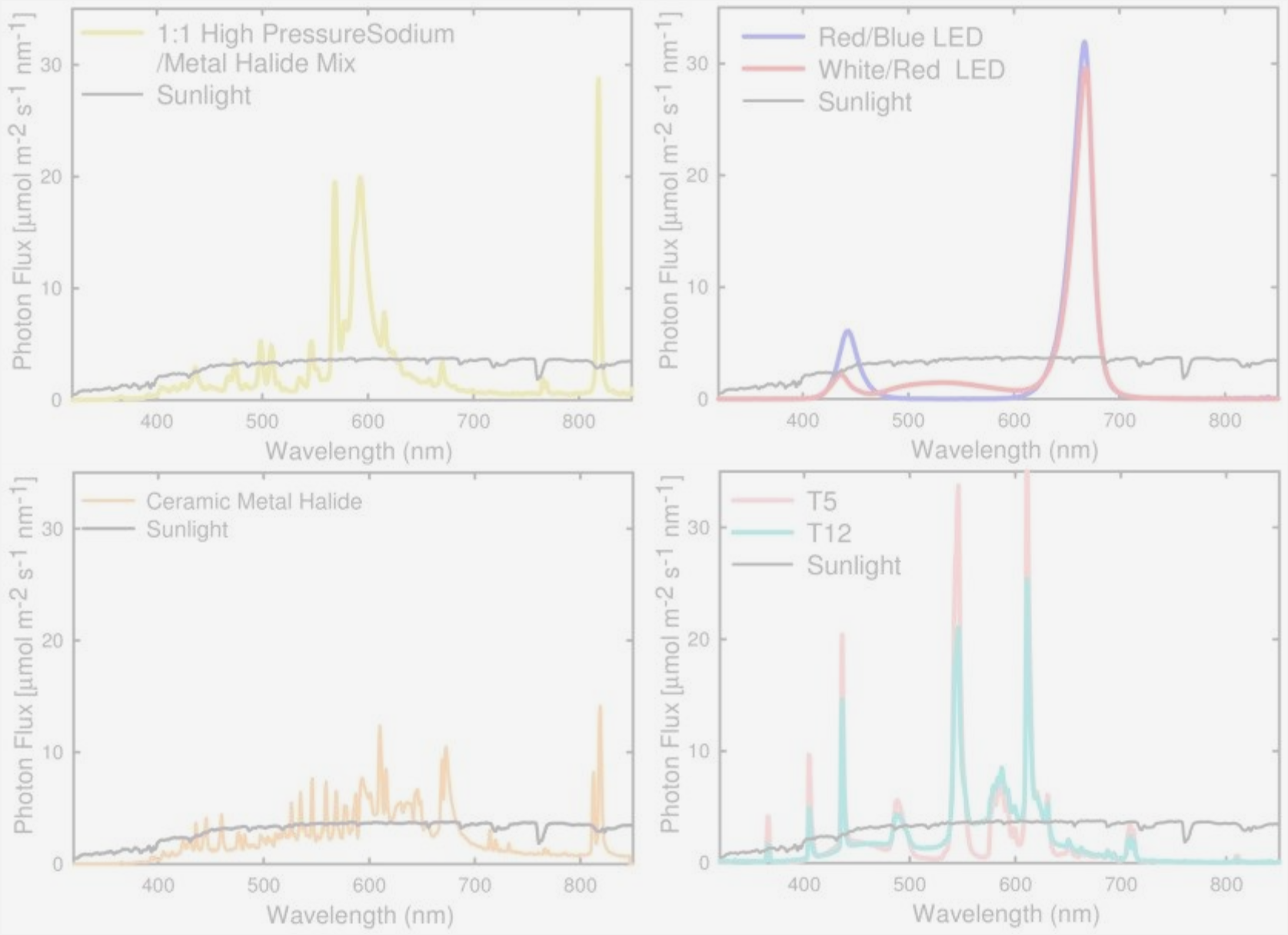
- T12 becoming obsolete/hard to find
- Higher light levels
- Better Light Quality
- Better Uniformity
- More Efficient

Uniformity

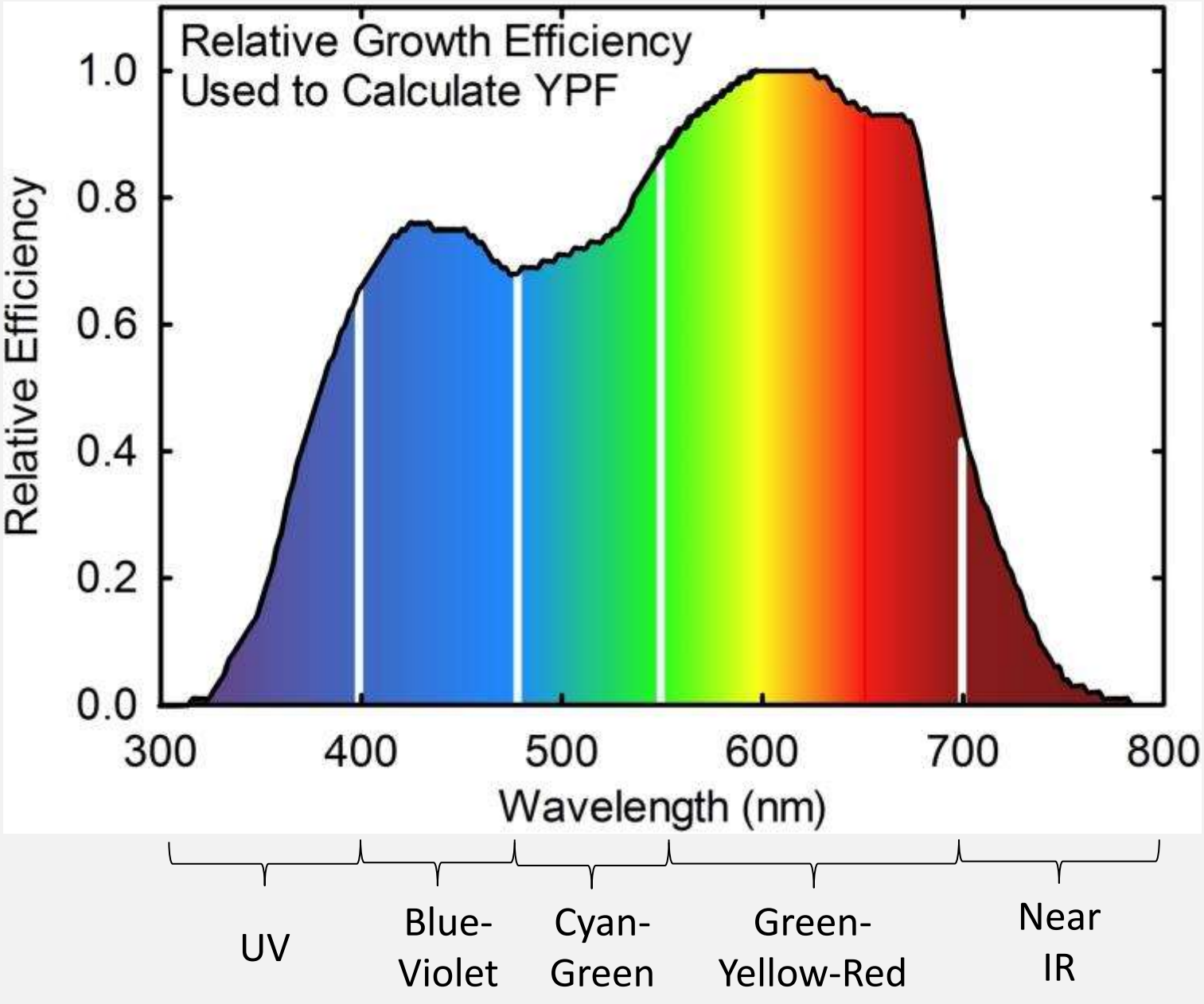

±50°
±34°
±18°
LED
400W
PARSource
1000W HPS
Sunlight Supply
1000W HPS
Cycloptics
315W CMH
Photosynthetic Photon Flux
(PPF; µmol m-2 s-1)
1400
1200
1000
800
600
400
200
0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Distance from center (m)
one meter below light


Fluorescent
HPS/MH Mix
CMH
50 cm below lights
80 cm below lights
cm from edge
0 20 40 60 80 100 120 140 160 180
0 10 20 30 40 50
% variation in PPF
Note scale from 0-50%

Light Quality



*Normalized to 1000 PPF

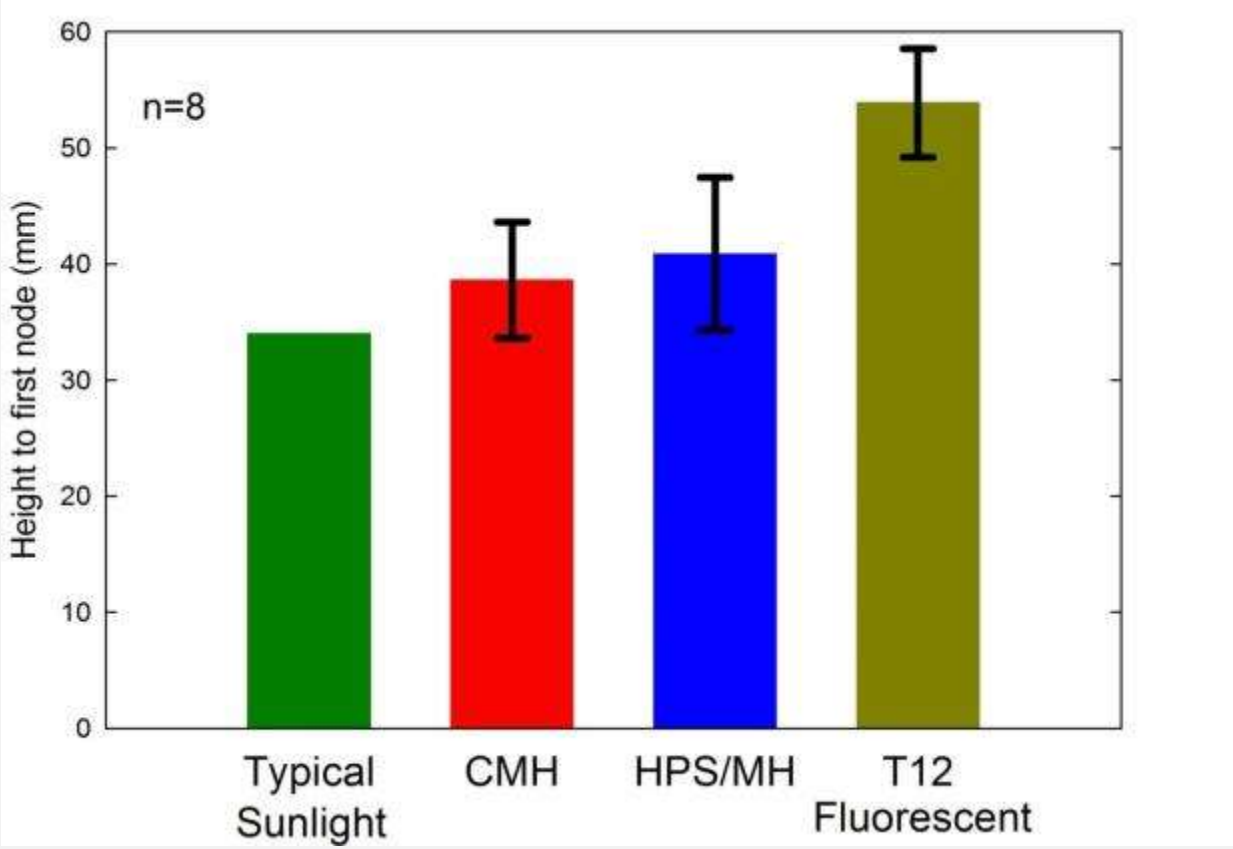

Relative Growth Efficiency
Used to Calculate YPF
Relative Efficiency
1.0
0.8
0.6
0.4
0.2
0.0
300
400
500
600
700
800
Wavelength (nm)
UV
Blue-
Violet
Cyan-
Green
Green-
Yellow-Red
Near
IR

Radiation distribution (% of PPF)

		%UVB (287-320)	%UVA (320-399)	Weighted UV[1]	Totals to 100% %Violet-Blue (400-475)	%Cyan-Green (476-550)	%Green-Yellow-Red (551-700)	%Near IR (701-850)
Sunlight-Solar Noon								
26-May	Clear	0.47	8.5	4.3	20.2	25.3	54.7	50.8
High Intensity Discharge								
HPS	Philips	0.01	0.8	0.3	4.4	6.0	89.7	56.6
Metal Halide	GE	0.13	8.3	2.9	18.9	22.7	58.4	26.5
1:1 HPS MH Mix*		0.06	1.7	0.5	10.6	14.8	74.6	21.1
Ceramic Metal Halide								
3100 K	Phillips	0.01	0.4	0.1	11.7	19.4	69.1	21.7
Fluorescent								
T12		0.49	2.6	2.6	17.5	20.9	61.6	3.9
T5		0.11	1.9	1.2	18.5	33.6	48.0	3.6
LEDs								
Red/Blue Mix	LSG[6]	0.00	0.1	0.0	15.3	0.4	84.4	1.2
White/Red Mix	LSG[6]	0.00	0.0	0.0	6.2	9.5	84.3	0.8

Soybean elongation in response to blue light

	Typical Sunlight	Ceramic Metal Halide	1:1 mix HPS/MH	T12 VHO Fluorescent
PPF	2000	900	1000	520
% Blue	20%	14%	11%	18%
Absolute Blue	400	130	110	90

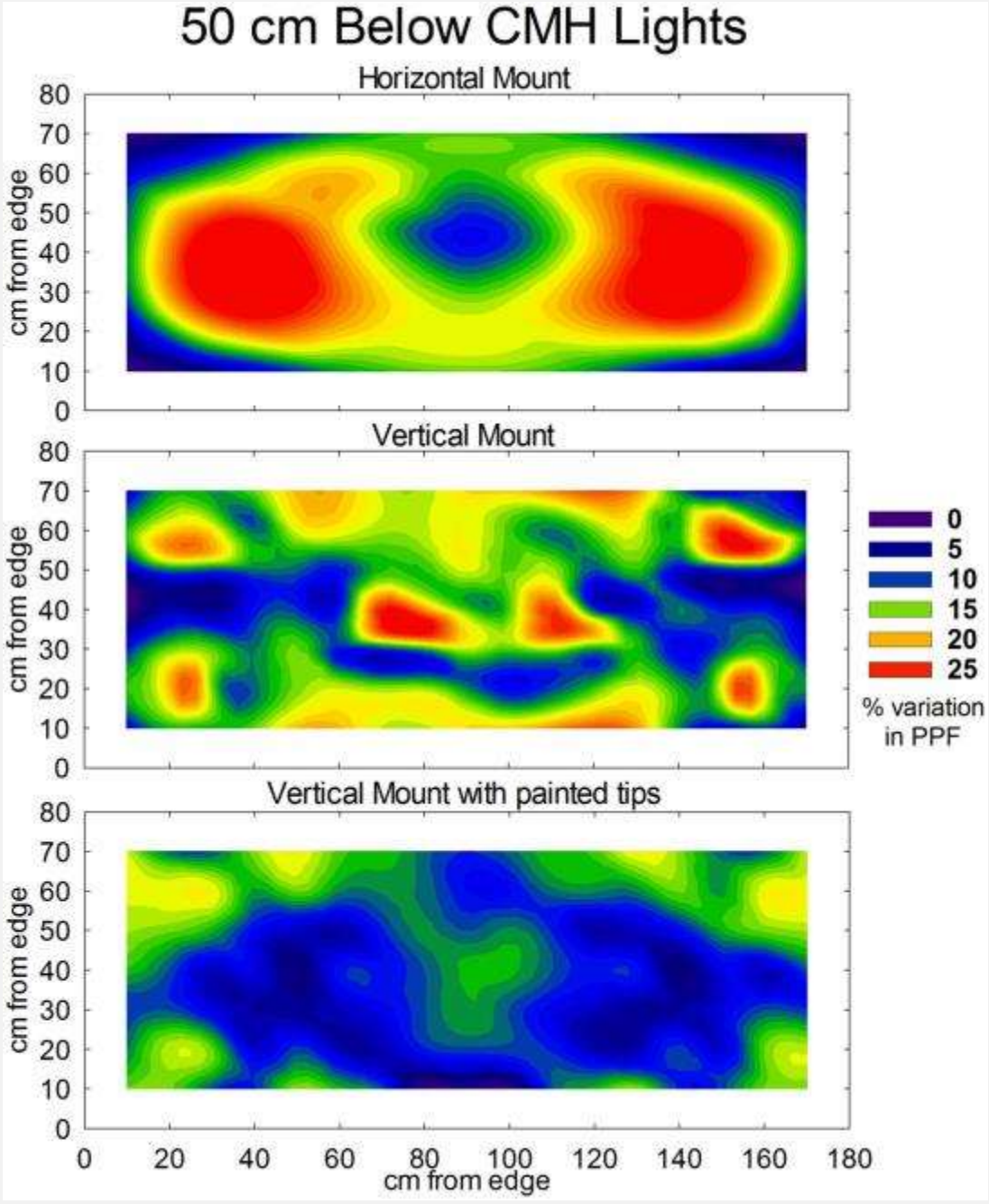


Efficiency

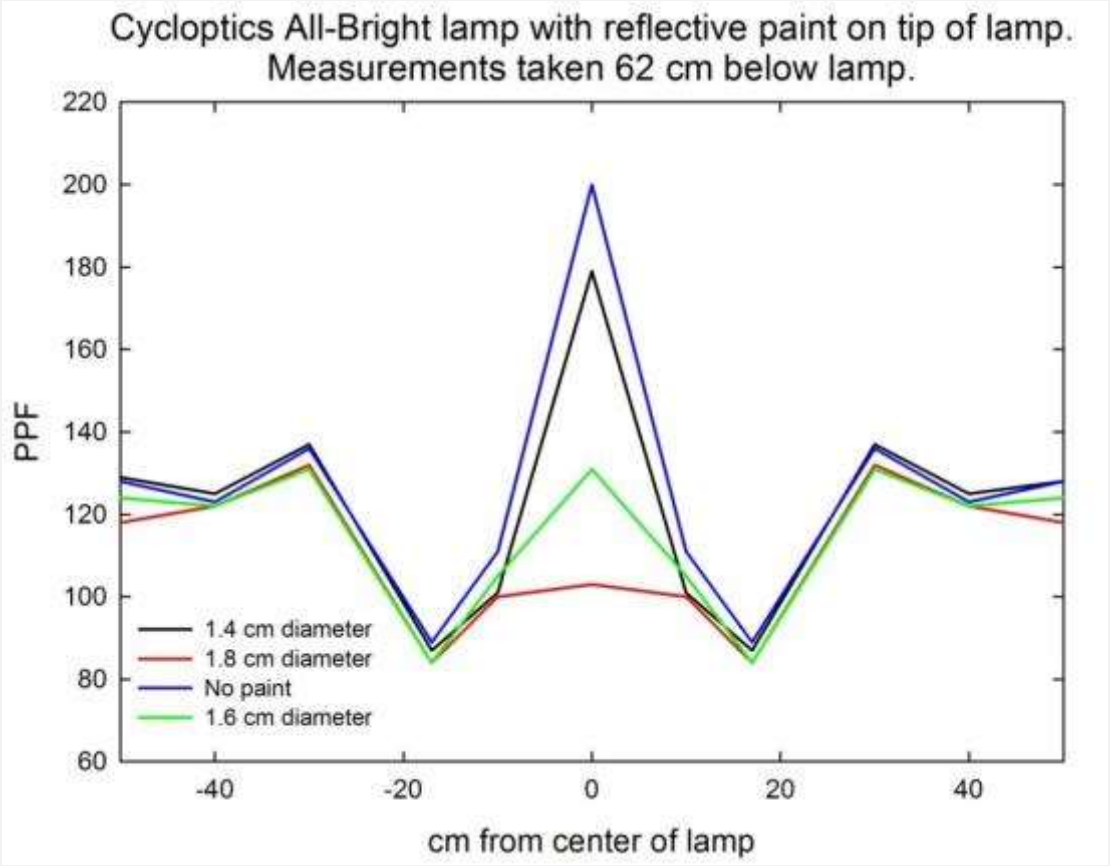
	Average PPF	Input kWatts	µmol / J	Coefficient of Variation (%)
T12 VHO Fluorescent	535	3.08	0.25	10.8
HPS/MH Mix	1495	4.66	0.46	9.2
Ceramic Metal Halide	1378	2.16	0.93	3.6

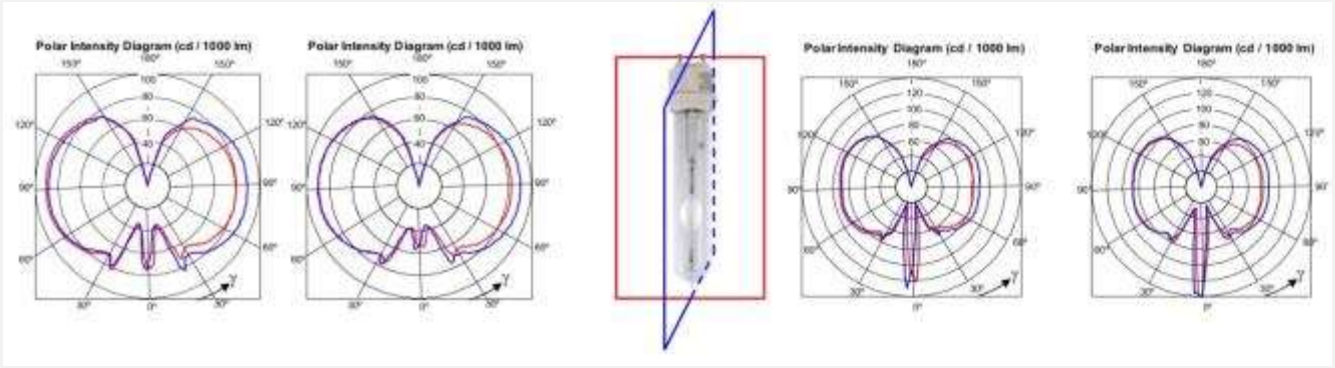
A step by step procedure for retrofitting a Conviron E15 chamber to CMH can be found at:
http://cpl.usu.edu/files/publications/factsheet/pub__3626113.pdf

Watch for “Hotspots”



Painting the lamp





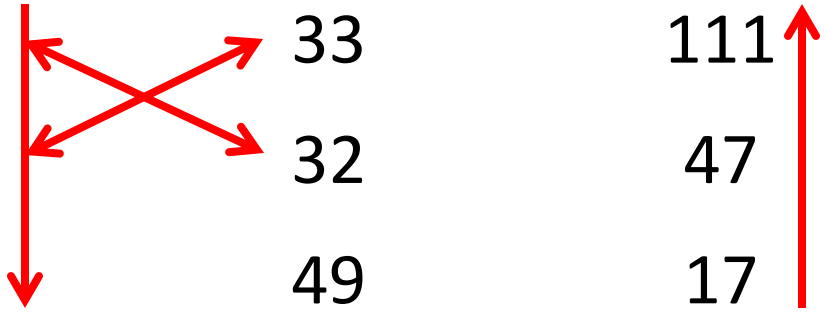
PPF efficiency and cost per mole photons
Assuming all radiation is captured by plants

Lamp Type and Ballast	Fixture Manufacturer See Table 4 for more information	PPF Efficiency[2] (µmol/J)	Cost of one Fixture[4] ($)	Fixtures needed per mmol photons per second[5]	Electric Cost per mol photons[6] $/($^{mol}/_{s}$)*yr	Five Year Electric plus Fixture Cost per mol photons[7] $/($^{mol}/_{s}$)*yr
High Pressure Sodium						
400 W Magnetic	Sunlight Supply	0.93	$200	2.44	$0.36	$0.41
1000 W Magnetic	Sunlight Supply	1.02	$275	0.92	$0.32	$0.33
1000 W Electronic	PARsource	1.30	$380	0.75	$0.25	$0.28
LED						
400 W Red/Blue	Lighting Sciences Group	1.60	$1,200	1.60	$0.21	$0.56
400 W Red/White	Lighting Sciences Group	1.51	$1,200	1.67	$0.22	$0.59
Ceramic Metal Halide						
315 W 3100 K (Agro)	Cycloptics	1.44	$700	2.07	$0.23	$0.49

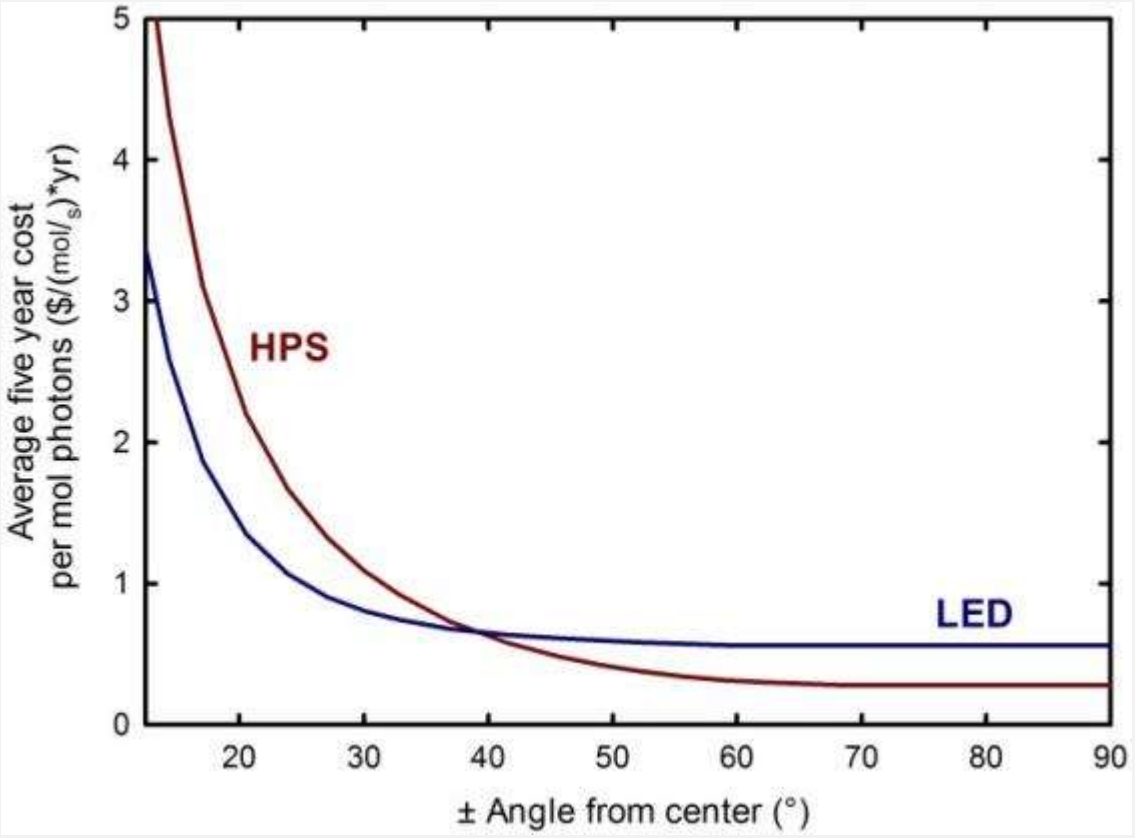
Assumes 3000 hours per year operation and $0.11/kWh.

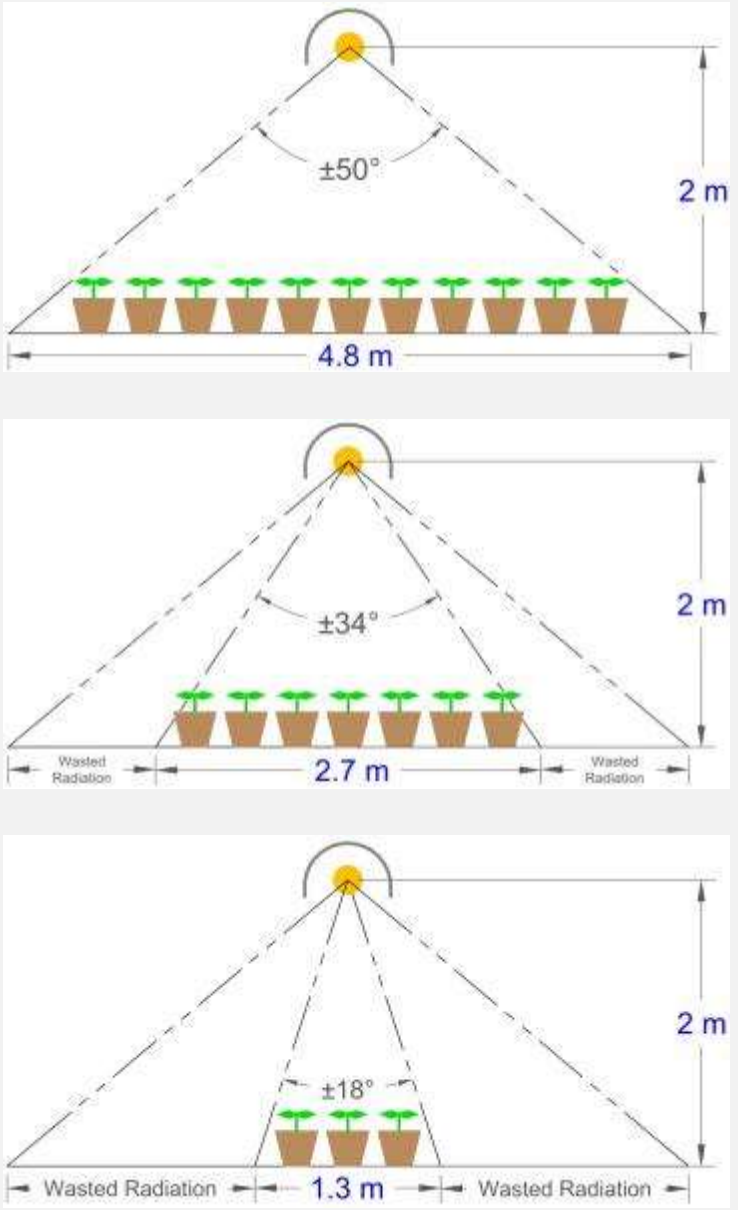
Importance of measuring in PPF

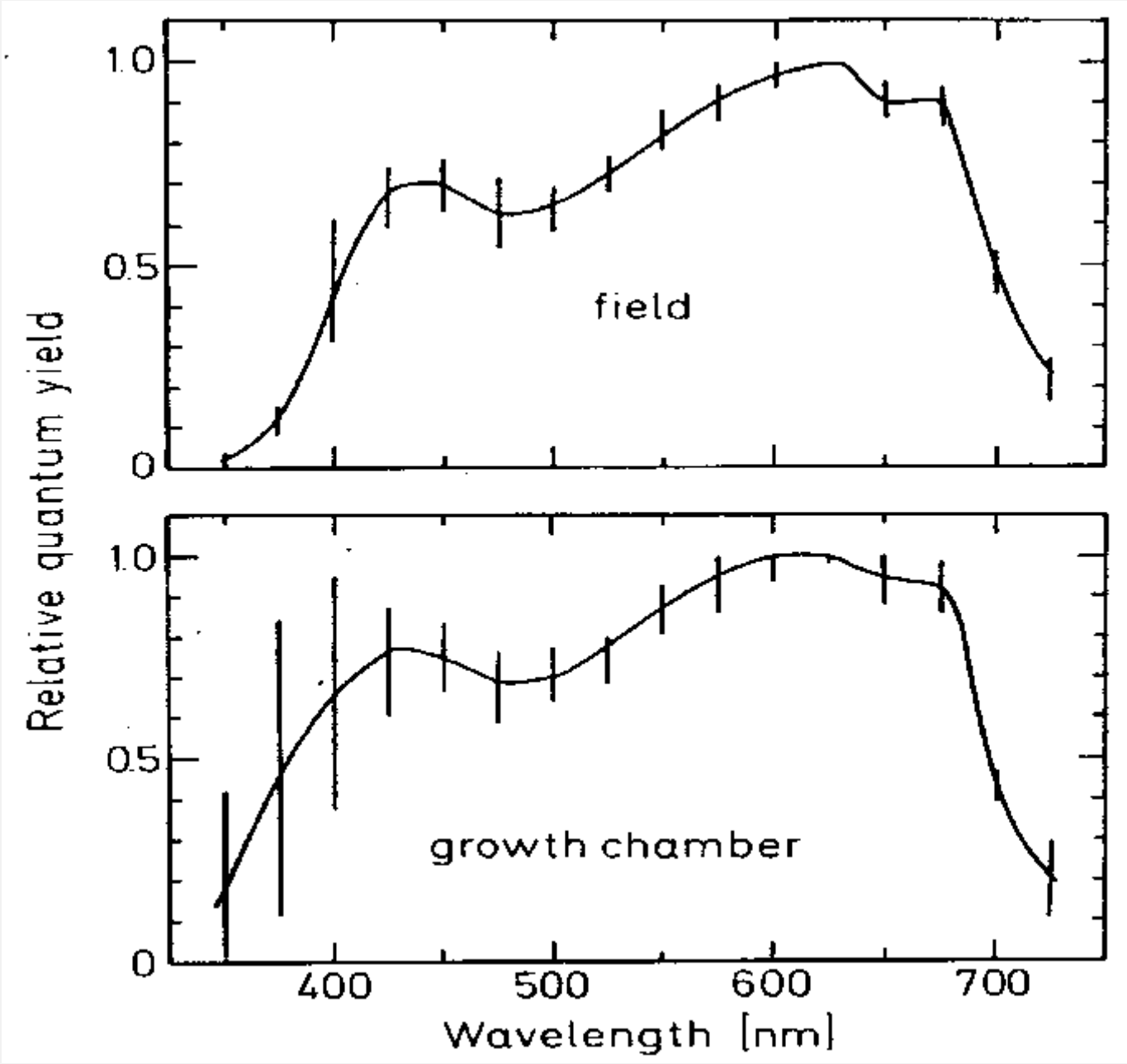
LED Color	Peak Wavelength or Temp.	PPF Efficiency (µmol/J)	Electrical Efficiency (%)	Luminous Efficiency (lm/W)
Cool White	5650 K	1.52	33	111
Red	655 nm	1.72	32	47
Blue	455 nm	1.87	49	17



When are LEDs most effective?







Original graphs from McCree, 1972

			Ratios important to Photos	Ratios important to	
			Totals to 100%		
		YPF / PPF	%Violet-Blue (400-475)	%Cyan-Green (476-550)	%Green-Yellow-Red (551-700)
Sunlight-Solar Noon					
26-May	Clear	0.901	20.2	25.3	54.7
High Intensity Discharge					
HPS	Philips	0.95	4.4	6.0	89.7
Metal Halide	GE	0.91	18.9	22.7	58.4
1:1 HPS MH Mix*		0.92	10.6	14.8	74.6
Ceramic Metal Halide					
4200 K	Philips	0.892	13.2	25.7	61.2
3100 K	Philips (Agro)	0.898	11.7	19.4	69.1
Fluorescent					
T12		0.89	17.5	20.9	61.6
T5		0.89	18.5	33.6	48.0
LEDs					
Cool		0.86	22.1	25.4	52.5
Red/Blue Mix	LSG[6]	0.89	15.3	0.4	84.4
White/Red Mix	LSG[6]	0.89	6.2	9.5	84.3
Compact Fluorescent					
Cool White	Sylvania	0.915	12.7	29.1	58.2
Incandescent		0.97	4.8	14.4	81.2