

Designers Lighting Forum

Light and health...and energy efficiency?

Robert Soler March 17th, 2020







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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.







Learning Objectives

At the end of the this course, participants will be able to:

- 1. Understand the physiological effects of light.
- 2. Calculate vertical foot-candles in designs
- 3. Meet criteria for WELL and CS without compromising energy efficiency
- 4. Employ color constancy in design applications







Agenda

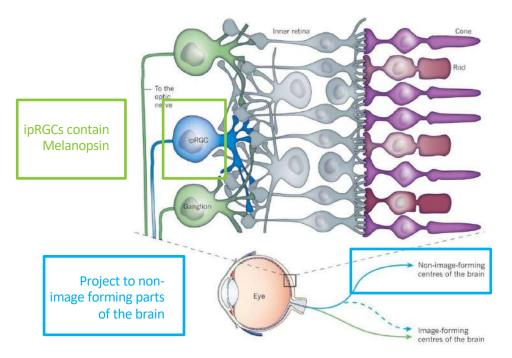
- What do we agree on?
- What we don't agree on, yet?
- How to do vertical light calculations
- How to meet the WELL criteria without compromising energy efficiency
- How to take this whole thing to the next level





Light and Health: What do we agree on?

- What it is
 - ipRGCs mediate different physiological effects
 - Direct effects
 - Alertness
 - Melatonin secretion
 - Cognition
 - Mood
 - Indirect effects
 - Circadian entrainment
 - Sleep
 - Mood (yup, again)
- Where it should be
 - Vertical not horizontal light
- How much
 - Each physiological effect appears to be greater than what is required for vision
- Brighter days and darker nights in the built environment
- Anything we do is better than what we are currently doing





What we don't agree on

- The exact role of rods and cones
- Which model should be used
 - LRC CS Model Vs. melanopic lux model Vs. CIE model
- Timing
 - First hour of the day?
 - First 4 hours of the day?
 - All day?
- Exactly how much?
 - 150 m-lux? (WELL V2 1 point)
 - 200 m-lux?
 - 240 m-lux? (WELL V2 3 points)
 - 500 m-lux?
 - CS = 0.3?
- A lot of the "movement" in criteria has been more of an interaction between what's best for light and health and what's best for comfort and energy
- Make no mistake, from a light and health standpoint, brighter is better.



CIE S 026 versus Lucas Model (WELL) for melanopsin

- CIE created a Melanopic DER (Daylight Efficiency Ratio)
 - How much melanopsin is stimulated by a light source relative to D65 (Daylight)
 - Melanopic EDI (Similar to melanopic lux)
 - A high melanopic EDI during the day is usually supportive for alertness, the circadian rhythm and a good night's sleep.
 - A low melanopic EDI in the evening and at night facilitates sleep initiation and consolidation. [CIE position statement]
 - Melanopic Daylight Efficiency Ratio
 - D65 would yield a melanopic DER of 1.
 - Highest sensitivity at 490nm
- WELL model (Melanopic Lux)
 - How much melanopsin is stimulated by a light source relative to Equal Energy Spectrum (~5555K)
 - Highest sensitivity at 490nm
 - Equal energy would yield an m/p = 1.
 - D65 would yield an m/p = 1.1
 - WELL m/p is about 10% higher than melanopic DER.
- Exact same weighting function!

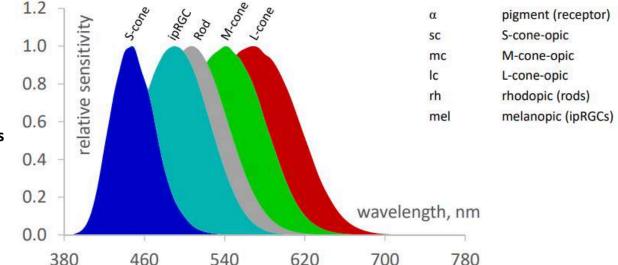
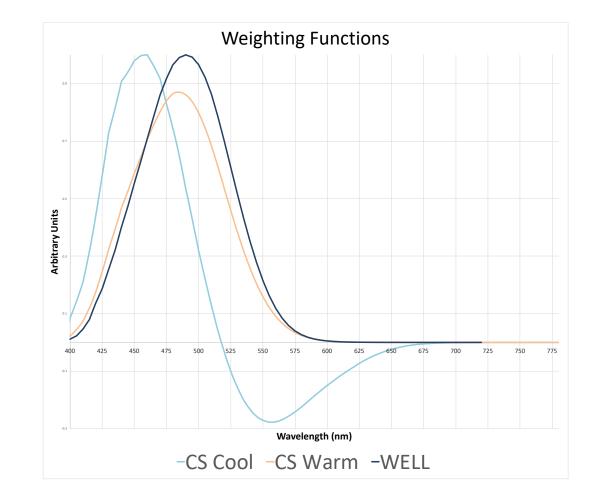


Image credit: CIE S 026 EDI Toolbox userguide https://www.nsvv.nl/wp-content/uploads/2019/03/CIE-S-026-EDI-Toolbox-Userguide-vE1.05x.pdf



WELL versus CS

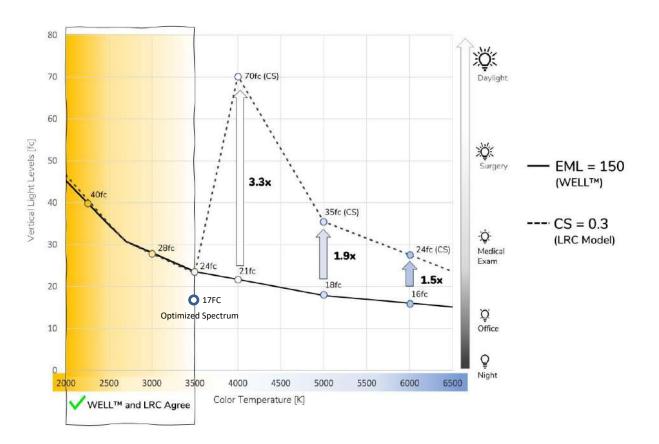
- The LRC has two models in one
 - Warm model is almost identical to WELL and CIE DER
 - Peak sensitivity at 485nm instead of 490nm
 - Cool model has this sub-additivity that they always talk about
 - Crossover is around 3500K
 - 3500K and warmer is "warm" model
 - Cooler than 3500K is "cool" model



LE:ucation

Application: How much we need for daytime versus color temperature

- Standard LED at 2200K requires 40FC vertical for BOTH CS and WELL
- Standard LED at 3000K requires 28FC vertical for BOTH CS and WELL
- Standard LED at 3500K requires 24FC vertical for BOTH CS and WELL
 - Spectrally Optimized will drop this down to 17FC
- At 3500K and warmer, the two models are the same
- Standard LED at 4000K requires 21FC for WELL and 3.3 times that for CS
- Standard LED at 5000K requires 18FC for WELL and 1.9 times that for CS
- Standard LED at 6000K requires 16FC for WELL and 1.5 times that for CS
- When the two models are NOT the same, CS requires significantly more light





Which color temperature do we want to use in our everyday daytime spaces?

| | | - | | A | | | | | |
|------|------|------|------|------|------|------|------|-------|----------|
| 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 | 3000 | 34440 | -10000 K |

| | Favorite CCT | l would never |
|-------|-----------------|------------------|
| 6500K | XX% | XX% |
| 5000K | XX% | XX% |
| 4000K | XX% | XX% |
| 3500K | XX% | XX% |
| 3000K | XX% | XX% |
| 2700K | XX% | XX% |

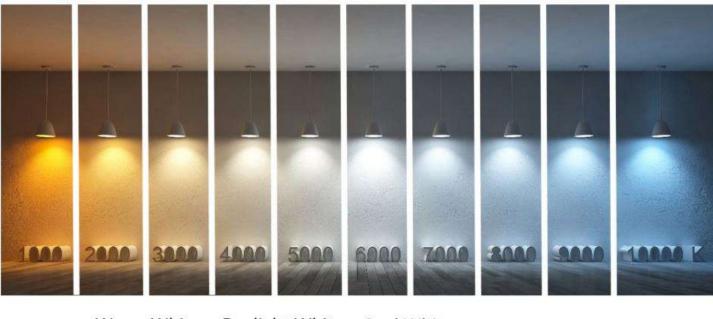
Warm White Daylight White Cool White 2700K-3300K 4200-4500K 5500-7000K

Reminder: CIE, LRC, and WELL all agree at 3500K and warmer

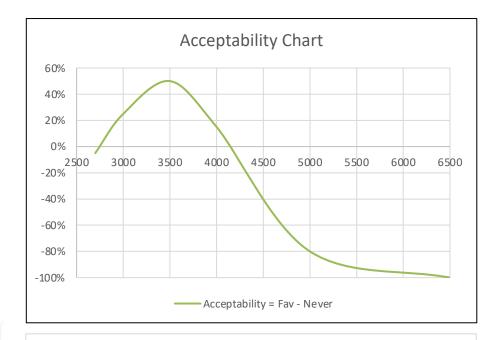
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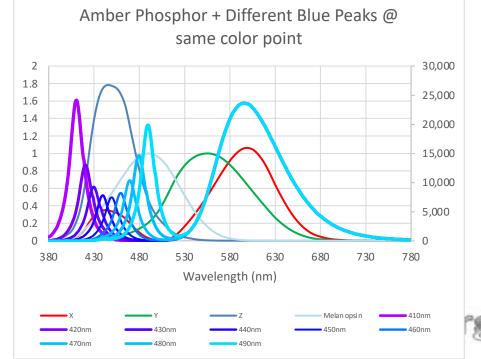
Matching with Preference

- My results from previous questionaires
- In order to maximize melanopic stimulus within the preference range, we have to consider the interaction with color vision



Warm White Daylight White Cool White 2700K-3300K 4200-4500K 5500-7000K

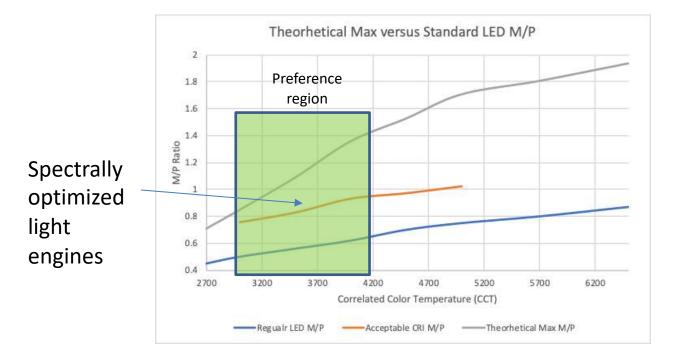


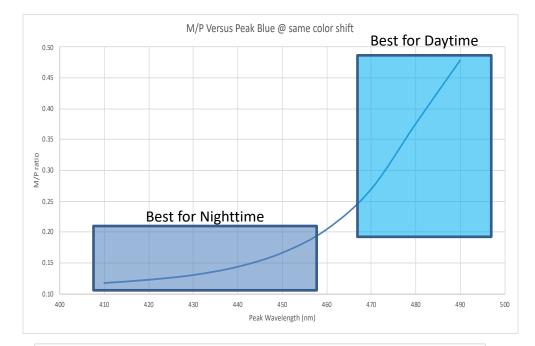


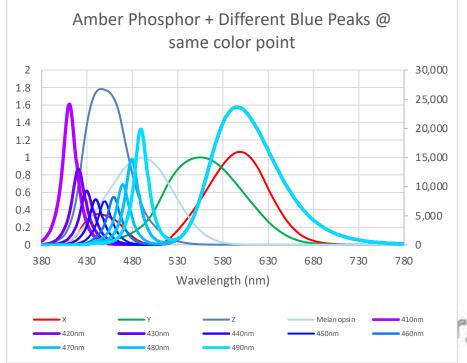
LE:ucation

Where should I put my peak?

- Colder color temperatures have the most capacity for melanopic rich spectrum
- We still have to make sure color rendering isn't compromised









Quick how to (WELL):

- Figure out M/P ratio
 - Some manufacturers will provide
 - Or you can calculate yourself
- Plug M/P ratio as a LLF
- Create a vertical calc plane



Figuring out the m/p

- Calculator can be found at: <u>https://standard.wellcertified</u>. .com/tables#melanopicRatio
- Click data tab to input your own SPD data

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| 16 | 450 | 0.035 | 0.5537 | 0.0380 | 0.0193 | 0.001324 | | | | | |
| 17 | 455 | 0.031 | 0.6297 | 0.0480 | 0.0193 | 0.001475 | | | | | |
| 18 19 | 460 465 | 0.023 | 0.7080 | 0.0600 | 0.0162 | | | | | | |
| 20 | 470 | 0.014 | 0.8603 | 0.0910 | 0.0117 | | | | | | |
| 21 | 475 | 0.012 | 0.9177 | 0.1126 | 0.0106 | | | | | | |
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| 66 67 | | 018171429 016028571 | | 8.75744 8.006453333 | 3.933855556 2.125175 | 5.2211 17.22972 4.86321875 7.46368 | | | 61 | 675 | 0.03375 | 0.027842857 | 12.87396 |
| 68 69 | 710 0.0 | 014642857 | 0.012916667 | 7.29395625 | 0.401571429 0.4005 | 4.534873333 16.4828 4.205153333 19.53248 | | | 62 63 | 680 0. 685 | 029991667 0.026575 | 0.025185714 0.02245 | 12.00995 11.16406 |
| 70 | 720 0.0 | 010983333 | 0.0101247 | 5.94519375 | 0.235371429 | 3.877925 15. 3319 | | | 64 | 690 0. | 023655556 | 0.0206 | 10.43118667 |
| 71 72 | | 0.0094557 | | 5.346246667 4.80328 | 0.015571429 0.014566667 | 3.600626667 15.50916 3.325413333 15.56464 | | | 65 66 | | 0.0207375 | 0.018414286 0.0164 | 9.5587 8.75744 |
| | Circad | | Data + | | di | | | 3 | 67 | 705 0. | 016028571 | 0.014557143 | 8.006453333 |
| - (#.)E. | = oncau | | т | 1 | | | | | 4 1 | Circad | dian | Data + | |

Melanopic Ratio Data Review View Table A^ Ξ ab Wrap Text ♥ Scientific Conditional For \$ • % 9 68 -98 **王 王 王** <u>+=</u> →= Merge & Center 🛩 Formatting as nges to one or more files. Do you want to recover them? - F -F G K L Equal Energy BIOS BIOS 4000K . le Fluorescent 4001 Constant 086667 0.088942857 1.316893333 10.2 834 6.61E-08 -3.23E-09 1.218 1.65856 0.087871429 1.70446 12.70802 6.87E-08 1.49E-08 856875 0.086866667 2.20519375 12 03508 3.85E-08 -2.42E-08 Insert columns to left of 0.808844444 986667 2.598086667 7.4267 3.22E-08 -2.20E-08 User 2 to add additional 746316 2.477175 10.73393659 2.10276 2.81E-08 -2.50E-08 sources. 851284 14.23881 23.82654 4 31E-08 1.74E-09 1.068 801961 0.848142857 4.8469 24.41185 7.51E-08 4.12E-08 4.9355125 23.8595 1.39E-07 1.05E-07 730625 1,448585714 1.81836 2.37715 5.644473333 24.52441 2.96E-07 2.59E-07 11.75395652 6.331693333 23.0354 6.39E-07 6.01E-07 826667 750127 22.86331753 21.2618829 23.28304 1.32E-06 1.32E-06 630899 6.404441176 44.45326 24.65627 2.60E-06 2.72E-06 685856 4.28675 19.9057639 27.33922 4.78E-06 5.19E-06 9.5806933 3 28.90782 7.73E-06 9.25E-06 079375 4.121685714 486667 4.23 10.34961333 29.34359 9.80E-06 1.30E-05 239125 3.900814286 11.0 98 30.4925 9.26E-06 1.30E-05 11.76 82 29.99563 7.39E-06 1.01E-05 1.92348 3.571657143 12.39346567 29.01958 6.93E-06 8.48E-06 453333 3.187814286 921875 3.132028571 12.94182941 29.2246 8.59E-06 9.83E-06 13.3596 667 29.58881 1.23E-05 1.34E-05 13.6837 667 29.58318 1.63E-05 1.74E-05 786667 6.116533333 973333 10.72654615 574125 9.566345455 13.9710625 28.33778 1.77E-05 1.86E-05 6.189957143 453333 14.19598 29.2656 1.60E-05 1.65E-05 446667 3.3182 14.3837 3667 28.93676 1.35E-05 1.37E-05 14.31 3225 28.39326 1.17E-05 1.21E-05 1.539942857 624375 153333 1.210757143 14.260-9333 28.74863 1.07E-05 1.13E-05 406667 0.826914286 14.164 9375 27.95267 1.00E-05 1.07E-05 5.86085 0.8258 14.028 3333 27.04093 9.69E-06 1.04E-05 13.834 0667 26.99912 9.49E-06 1.03E-05 866667 0.934114286 455625 5.608104545 13.639 3125 27.13098 9.40E-06 1.03E-05 13. 2994 27.00314 9.37E-06 1.02E-05 933333 29,53066796 433333 75.41515328 13.272 5333 26.66868 9.38E-06 1.01E-05 .069025 61.27502029 17.821 0549 26.39452 9.51E-06 1.01E-05 848229 13.64250476 29.5 7098 26.54004 9.70E-06 1.02E-05 113713 3.532754545 18.445 1818 25.79795 9.98E-06 1.04E-05 353684 1.391525 12.68 9625 25.03495 1.04E-05 1.06E-05 198667 1.199028571 12.596 3333 24.71014 1.08E-05 1.09E-05 691333 6.377933333 12.54113125 23.8177 1.14E-05 1.15E-05 957059 15.62201143 12.4278333 24.45848 1.22E-05 1.20E-05 14.39065977 23.76463 1.30E-05 1.27E-05 122333 14,76690909 8.82074 18.47862308 15.0175 059 24.4215 1.39E-05 1.35E-05 12.0474 333 23.40605 1.49E-05 1.43E-05 16.49222903 793125 683333 7.89120625 12.0537 23.26213 1.58E-05 1.50E-05 12.0601375 22.7122 1.67E-05 1.57E-05 4614375 4.030433333 172667 18.64042625 11.9303933 22.6133 1.74E-05 1.63E-05 8.37778 34.09730719 11.86397 33 21.98297 1.80E-05 1.68E-05 537375 9.68624 11.70473125 22.1309 1.85E-05 1.71E-05 960667 7.742375 11.49552 21.97493 1.88E-05 1.73E-05 437333 8.486135714 11.338333 3 21.01736 1.88E-05 1.73E-05 115625 3.837385714 11.07693125 19.68272 1.87E-05 1.71E-05 556667 1.566871429 10.7973 20.38542 1.85E-05 1.68E-05 20.54702 1.81E-05 1.63E-05 672667 1.565833333 10.51950625 794975 1.619557143 10.18376667 20.69576 1.75E-05 1.57E-05 023333 19.5565 1.67E-05 1.49E-05 1.618414286 9.790493333 9.41503125 20.81234 1.59E-05 1.41E-05 584667 1.179928571 962575 1.452228571 8.977146667 19.62564 1.50E-05 1.33E-05 9.97618 1.40E-05 1.23E-05 5.28056 1.177771429 8.56572 866375 0.957957143 8.1318125 9.85317 1.30E-05 1.13E-05 7.670653333 19 36595 1.19E-05 1.03E-05 725333 0.792828571 2.87396 1.229214286 7.231993333 19.70443 1.08E-05 9.36E-06 6.80601875 18.74204 9.86E-06 8.47E-06 2.00995 1.5563 6.38232 16.2408 8.90E-06 7.62E-06 6.088933333 17.58107 8.00E-06 6.80E-06 5.5994 17.34300 7.15E-06 6.03E-06 1.16406 1.008457143

0.4059

1.69665

2.125175

5.2211 17.22972 6.35E-06 5.28E-06

4.86321875 17.46368 5.52E-06 4.65E-0

3.933855556

LE:ucation

- Calculator can be found at: <u>https://standard.wellcertified.com</u> /tables#melanopicRatio
- Click data tab to input your own SPD data
- In this instance, we see an m/p of 0.911 (We'll use 0.9 for our example)

| | • • A | utoSave | JOFF A | ⊟ & 5 · | - U = | | | | | | | | | Me 🔤 | elanopi |
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| F | Recover Un | saved Wor | kbooks. We | e were able to | save changes | to one o | r more fil | es. Do you want to re | ecover them | ? | | | | | |
| | \$ | XV | fx BIOS 4 | юоок | | | | | | | | | | | |
| | A | В | с | D | E | F | G | н | | T. | | J | К | L | L. |
| k (i | nm) 🔻 Lam | | circadian 💌 | | | lamp*v 💌 | | Source | | | Melanopic | | - | | |
| | 380 | 0.000 | 0.0009 | 0.0000 | 0.0000 | -1.3E-13 | | BIOS 4000K | | | - | 0.911 | | | |
| | 385 | 0.000 | 0.0017 | 0.0001 | 0.0000 | 8.94E-13 | | Sample LED 27 | 00 K | | Click here | for data input | | - | |
| | 390 395 | 0.000 | 0.0031 | 0.0001 | 0.0000 | -2.9E-12 | | Sample LED 40 | 00 K | ored | source (ab | (000 | | | |
| | 400 | 0.000 | 0.0114 | 0.0002 | 0.0000 | -16-11 | | Sample Fluores | cent 2950 | V | | | s) into Data sh | neet. | |
| | 405 | 0.000 | 0.0228 | 0.0006 | 0.0000 | 1,118-12 | | Sample Fluores | cent 4000 | Ksto | the left of | User 2 on the | Data sheet. | | |
| | 410 | 0.000 | 0.0462 | 0.0012 | 0.0000 | 4.99E-11 | | Sample Fluores | cent 6500 | K or | modeled lux | to calculate e | quivalent mela | nopic lux. | |
| | 415 420 | 0.000 | 0.0795 | 0.0022 | 0.0000 | 2.29E-10 1.04E-09 | | Sample Overca | st | | mmm | mmm | erereren erer | HIM | 17111 |
| | 425 | 0.000 | 0.1871 | 0.0073 | 0.0000 | 4.39E-05 | | 3500K | | | | | | | |
| | 430 | 0.000 | 0.2539 | 0.0116 | 0.0000 | 1.53E-08 | | 4000K | | | 1 | | | | |
| | 435 440 | 0.000 | 0.3207 | 0.0168 | 0.0000 | 4.58E-08 | | | | 1/ | | X | | | |
| | 445 | 0.000 | 0.4740 | 0.0298 | 0.0000 | 2.76E-07 | | | | X | / | | | | |
| | 450 | 0.000 | 0.5537 | 0.0380 | 0.0000 | 4.94E-07 | | | \mathcal{A} | 77 | - | | | | |
| | 455 | 0.000 | 0.6297 | 0.0480 | 0.0000 | 6.24E-07 | | // | | 1.1 | | | | | |
| | 460 465 | 0.000 | 0.7080 | 0.0600 | 0.0000 | 6.06E-07 6.27E-07 | | | | / | 1 | | | | |
| | 470 | 0.000 | 0.8603 | 0.0910 | 0.0000 | 8.94E-07 | | | | | | | | | |
| | 475 | 0.000 | 0.9177 | 0.1126 | 0.0000 | 1.516-06 | 5 | | | | ~ | | | | |
| | 480 | 0.000 | 0.9656 | 0.1390 | 0.0000 | 2.42E-06 | 5 | 380 400 420 440 | 460 480 50 | 0 520 | 540 560 | 580 600 6 | 20 640 660 | 680 70 | 0 720 |
| | 485 | 0.000 | 0.9906 | 0.1693 | 0.0000 | 3.15E-06 3.43E-06 | | 300 100 120 110 | | | circae | | | 000 70 | |
| | 495 | 0.000 | 0.9920 | 0.2586 | 0,0000 | 3.54E-06 | | | | | | | | | |
| | 500 | 0.000 | 0.9660 | 0.3230 | 0.0000 | 3.91E-06 | | 1 11 | | | | | | | - |
| | 505 | 0.000 | 0.9223 | 0,4073 | 0.0000 | 4.6E-06 | | WELL | NATIONAL | | | | | | |
| | 515 | 0.000 | 0.7852 | 0.6082 | 0.0000 | 6.33E-06 | 5 | | UTE" | | | | | | - li |
| | 520 | 0.000 | 0.6996 | 0.7100 | 0.0000 | 7.31E-06 | 5 | | | | | | | | |
| | 525 530 | 0.000 | 0.6094 0.5193 | 0.7932 0.8620 | 0.0000 | 8.17E-06 8.79E-06 | 5 | ~ | | | | | | | - |
| | 535 | 0.000 | 0.4325 | 0.9149 | 0.0000 | 9.24E-06 | | | | | | | | | |
| | 540 | 0.000 | 0.3517 | 0.9540 | 0.0000 | 9.64E-06 | 5 | | | | | | | | |
| | 545 | 0.000 | 0.2791 | 0.9803 | 0.0000 | 16-05 | | - | | | | | _ | - | _ |
| | 550 555 | 0.000 | 0.2157 | 0.9950 | 0.0000 | 1.03E-05 | | | | | | | | | - |
| | 560 | 0.000 | 0.1185 | 0.9950 | 0.0000 | 1.08E-05 | | | | | | | | | |
| | 565 | 0.000 | 0.0843 | 0.9786 | 0.0000 | 1.13E-05 | | | | | | | | | |
| | 570 575 | 0.000 | 0.0587 | 0.9520 | 0.0000 | 1.14E-05 | | | | | | | | | |
| | 580 | 0.000 | 0.0269 | 0.8700 | 0.0000 | 1.17E-05 | | | | | | | | | |
| | 585 | 0.000 | 0.0179 | 0.8163 | 0.0000 | 1.178-05 | | | | | | | | | |
| | 590 595 | 0.000 | 0.0118 | 0.7570 | 0.0000 | 1.14E-05 | | | | | | | | | |
| | 600 | 0.000 | 0.0077 | 0.6949 | 0.0000 | 1.09E-05 | | | | | | | | | |
| | 605 | 0.000 | 0.0033 | 0.5668 | 0.0000 | 9.52E-06 | | | | | | | | | |
| | 610 | 0.000 | 0.0022 | 0.5030 | 0.0000 | 8.6E-06 | | | | | | | | | |
| | 615 620 | 0.000 | 0.0014 | 0.4412 | 0.0000 | 7.63E-06 | | | | | | | | | |
| | 625 | 0.000 | 0.0006 | 0.3210 | 0.0000 | 5.49E-06 | | | | | | | | | 1 |
| | 630 | 0.000 | 0.0004 | 0.2650 | 0.0000 | 4.45E-06 | 5 | | | | | | | | |
| | 635 640 | 0.000 | 0.0003 | 0.2170 | 0.0000 | 3.54E-06 | | | | | | | | | |
| | 645 | 0.000 | 0.0002 | 0.1750 | 0.0000 | 2.06E-06 | | | | | | | | | |
| | 650 | 0.000 | 0.0001 | 0.1070 | 0.0000 | 1.516-06 | | | | | | | | | |
| | 655 | 0.000 | 0.0001 | 0.0816 | 0.0000 | 1.09E-06 | | | | | | | | | |
| | 660 | 0.000 | 0.0000 | 0.0610 | 0.0000 | 7.5E-07 | | | | | | | | | |

Data

+

Circadian



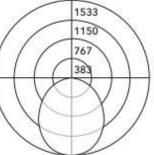
Open Office with a troffer

- Open Office 66' x 31'
- 5 or 6 long tables with workstations
- Notes: tables facing walls are going to suffer on vertical lux

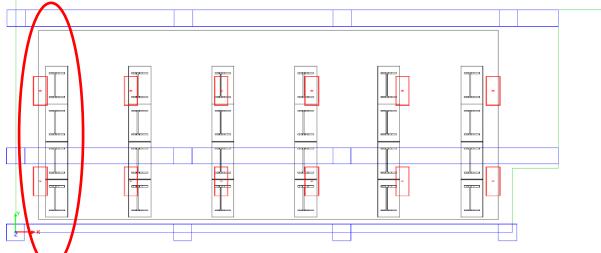
Photometrics

Satine Lens Test # ITL88934 Catalog # LU24A.84

Test # ITLB8934 Catalog # LU24A.840MO Lumens 4178 im Watts 32.2 W Efficacy 130 LPW









Adding m/p ratio into calcs

• Uploading m/p (0.9) as a LLF

| Define Luminaire | | | | × |
|--|-----------------|-------------------|------------------|--------------|
| 🛱 Instabase 🔹 🦓 Audit 🔹 💱 Downloaded 🛛 🍃 Collection 🖆 | Select 🗰 Find | ✓ Smart Symbols | 🖌 Auto Define | |
| Defined Luminaires - Drag-and-drop here! Use Alt+Arrows keys to reorder list | | | | Close |
| Label Tag Desc | cription | Lo | cations 🔨 🔨 | |
| | B-A-O-B40-B40-4 | 0 | | Help |
| | B-A-O-B40-B40-4 | 0 | | |
| | 4A-840L0 | 0 | | Relabel |
| | 4A-840M0 | 0 | | Delete |
| LU24A-840MC LU2 | 4A-840MO | 12 | | |
| SC2134 4000 C.C.C | | 0 | ~ | Add/Redefine |
| General | | | Pendant Mounted | |
| Label LU24A-840MO BIOS 👻 Tag | | | c: Attach to Z= | |
| | | | I | |
| | Def | aults O Static: I | Length = | |
| Definition | - Arrangement | - Symbols | | |
| Lumens Per Lamp N.A. Number Of Lamps 224 | SINGLE | 1200X300 MM DOWN | Render Mode | |
| Luminaire Lumens 4179 Efficiency (%) | | | Housing | |
| Luminaire Watts 32.2 S/P Ratio 1 | * | | | |
| Total LLF 0.900 Specity | | | Luminous | |
| | Arm Length | 1200X300 MM DOWN | Model Mode | |
| X Y Z | Ann congar [0 | | | |
| Luminous Box: LLHC -1.917 -0.919 -0.01 | | + | Line Width/Color | |
| URHC 1.917 0.919 0 | | | Pixel 🛨 📕 | |
| Photometric File | · | | | |
| Description Classification LCS |) | Canc | iela C LCS | |
| Filename: C:\Users\Erica Voss\Documents\BIOS MARKETING\BIOS Pre | 1 | | | |
| [TEST] ITL88934-GONIOPHOTOMETRY | | | | |
| [TESTLAB] INDEPENDENT TESTING LABORATORIES, INC. | | | | |
| [ISSUEDATE] 02/22/17 [MANUFAC] PINNACLE ARCHITECTURAL LIGHTING | | | 8944 A C C C | |
| ÍLUMCAT1 LU24A-840MO | | | | |
| LUMINAIRE FABRICATED METAL HOUSING WITH WHITE PAINTED | | Pt | Contro State | |
| | | | 174448887 | |
| [ESNA:LM-63-2002 [INPUT_ELECTRICAL]277.0 VOLTS, 32.2 WATTS, 0.121 AMPS | | | X44+X/ | |
| PAINTREFLIST.1 % | 1 | | | (and a) |
| < >> | | | More | |
| | 1 | | | |

LE: ucation

Setting up vertical calcs

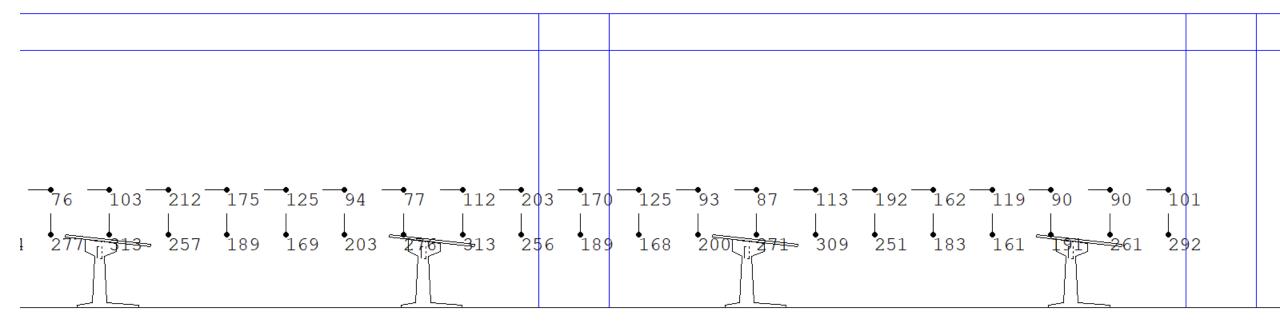
- Must use 2 point calculation
- Tilt light meter 90 degrees
 - Orientation dictates which direction looking
 - Turn on meter indicator to see direction
- 4' above finished floor

| Model Toolkit | General |
|---|--|
| Luminaire Rooms/Objects Drawing/Schedules Calculations Iff Automatic Placement Add: Iff Y | Label Ev Description Vertica Point Spacing: Left-To- I Center Points Relat Analysis Type |
| Add Colculation Gdd | C Horizontal Meter A Normal To Grid Fixed: Orient C Variable - Meter A Summary |
| | Average Maximum and Minir Average/Minimum Maximum/Minimum Maximum/Average Number Of Points Coefficient of Variat Uniformity Gradient |

| Calculation Points - 2 Pt. Grid | | × |
|--|--|---|
| General Label Ev | | Ok |
| Description Vertical Illuminance | | Cancel |
| Point Spacing: Left-To-Right 5 Top-To-Bottom | 5 ft Text Size 1.5 | Help |
| Center Points Relative To Grid Boundaries | | |
| Analysis Type | | Highlight |
| Light Meter | | Isolines |
| O Normal To Grid | | 2 Pt. Grid |
| Fixed: Orient Tilt J90 Variable - Meter Aiming Point: X | Z Specify | · · · · ² |
| Summary ✓ Average ✓ Maximum and Minimum ✓ Average/Minimum Ratio ✓ Maximum/Minimum Ratio ✓ Maximum/Average Ratio Maximum/Average Ratio Number Of Points Coefficient of Variation Uniformity Gradient % Points in Range: 25 To Add Grid Z-Coord: 1st Point 4 2nd Point | Display Options Decimals 0 Color Color Grid Perimeter Lines Visible Mark Points Meter Indicator Labeling | 1 Consider using 'Automatic Placement'. Points associated with a surface calculate faster (when using 'Full Radiosity Method'). |



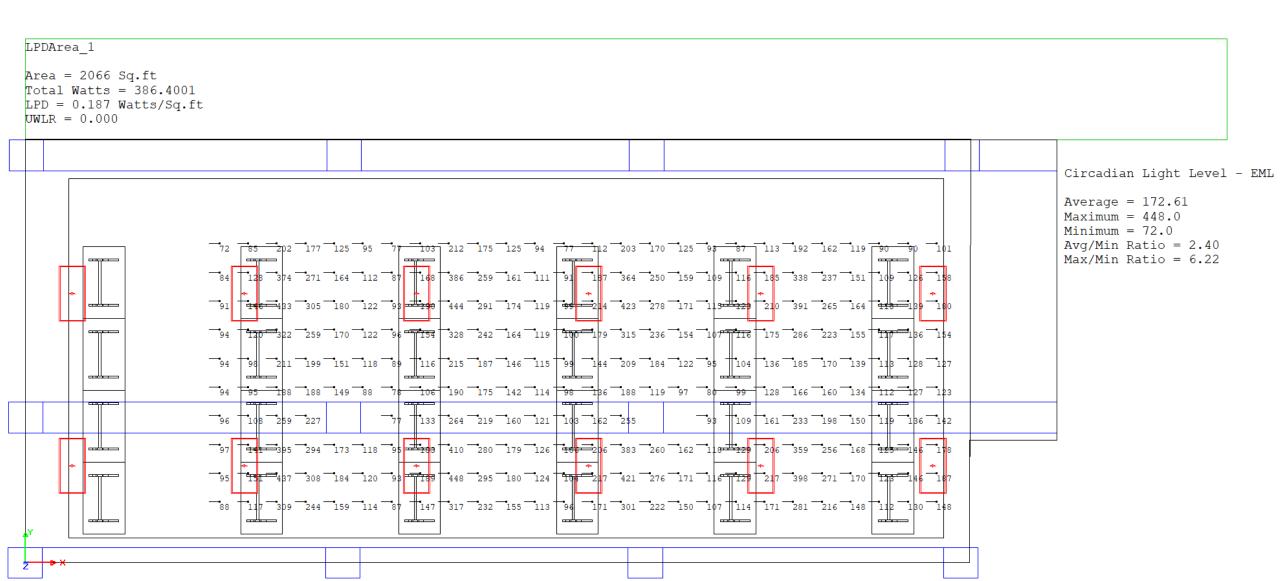
Elevation view of horizontal calc plane and vertical calc plane





| A T L | ota: PD = | - 2 = 2 L Wa = 0. | - 2066 : atts = | Sq.ft = 386.400 Watts/Sq. | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------------|--------------|----------------------------|-----------------------|---------------------------------|----------------------|-------------------------|----------------------------|--------------------------|--------------------------|--------------------------|---|--------|----------------------------------|--------------------------|--------------------------|----------------------------------|--------------------------------------|----------------------------------|--------------------------|--------------------------|--|----------------------------------|--------------------------------------|--------------------------|--------------------------|----------------------------------|--------------------------|--|------------------------------|---|----------|
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Vis | al Light Leve | ls - Lux |
| | | ↓ | | | 47 53 42 29 | 6 48 7 32 | 431 479 3335 0276 | 282 308 272 218 | 241 261 244 217 | 309 340 299 245 | 307 3 47 5 5 42 7 4 42 7 4 2 97 3 2 62 2 | | 2 281 2 309 3 276 4 233 | 240 262 244 216 | 310 340 300 243 | 477 5 555 6 927 4 298 3 | 9 430 94 482 93 391 927 281 | 0 280 2 306 1 276 7 233 | 238 256 234 191 | 306 334 287 227 | 474 5. 332 6. 417 4: 287 3. | 66 42 41 47 87 38 19 28 | 25 273 75 300 87 270 80 227 | 230 251 234 207 | 297 323 286 232 | 461 −518 −407 −283 − | 541 615 465 301 | | Ave: Max: Min: Avg; | uminance (Lux) cage = 345.21 imum = 647.0 imum = 157.0 /Min Ratio = 2 /Min Ratio = 4 | |
| | | | | | 35 | 3 39 | 3 324 | 224 | | | 344 3 | 95 330 | 254 | 231 | 269 | 355 3 | 96 332 | 2 | | 255 | 346 3 | 95 32 | 27 247 | 222 | 260 | 346 | 381 | | | | |
| A ^Y | | + | | - | 53 | 2 53 | 9 477 | 300 | 252 | 332 | 49 5 | 3 479 | 305 | 258 | 336 | 53 | 38 4 74 | 296 | 250 | 332 | 530 6: | 36 47 | 74 301 | 253 | '331 | 530 | ≁ 647 | | J | | |
| z | Þ | × | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |







Data

leducation.org

| | Standard Troffer design w/ Standard 4000K LED | High output design to meet WELL criteria | Troffer (3,950 lm @ 37.4W) – Spectrally optimized 3500K LED |
|------------------|---|--|---|
| Fixture Output | 4,179 lm | 5,403 lm | 3,950 lm |
| Fixture Wattage | 32.2 W | 42.5 W | 37.4 W |
| Fixture efficacy | 129 lm/W | 129 lm/W | 104 lm/W |
| ССТ | 4000K | 4000K | 3500K |
| m/p | 0.61 | 0.61 | 0.83 |
| LPD | .187 | .246 | .215 |
| Horizontal lux | 345 [32 FC] | 446 [41.5 FC] | 326 [30 FC] |
| Vertical lux | 191 [18 FC] | 246 [23 FC] | 181 [16.8 FC] |
| Vertical m-lux | 116 | 150 | 150 |

Spectrally optimized fixtures may "under perform" in efficacy, but when do better in total energy consumption when trying to achieve circadian metrics



In review

- Brighter days and darker nights is the goal
 - The brighter the day, the better
 - The darker the night, the better (didn't get into this much, but trust me)

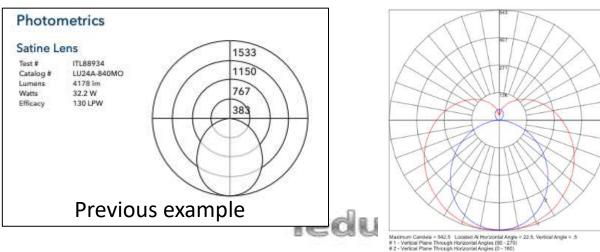
- Vertical lux is what we need, not horiztonal
- ALL MODELS AGREE AT 3500K and warmer
- That's GREAT, because we like 3500K and warmer.



Getting more vertical lux

• More luminous pendants can get more vertical lux







Data

| | Luminous pendant design w/ Standard 4000K LED | High output design to meet WELL criteria | Luminous pendant design w/ Spectrally optimized 4000K LED |
|------------------|---|--|---|
| Fixture Output | 2,339 lm | 2,690 lm | 2,339 lm |
| Fixture Wattage | 27.2 W | 32.3 W | 33.4 W |
| Fixture efficacy | 85 lm/W | 85 lm/W | 70 lm/W |
| ССТ | 4000K | 4000K | 4000K |
| m/p | 0.61 | 0.61 | 0.91 |
| LPD | .384 | .44 | .45 |
| Horizontal lux | 320 [30 FC] | 368 [34 FC] | 320 [30 FC] |
| Vertical lux | 214 [20 FC] | 246 [23 FC] | 214 [20 FC] |
| Vertical m-lux | 130 | 150 | 194 |



Putting the light where you need it

- Take a page out of task lighting's handbook
- But now, the "task" has changed





But let's go a little further

- Why do we dislike 6500K, when it's 6500K outside
- What if we can change preference?
- What if what you see is not what you get?





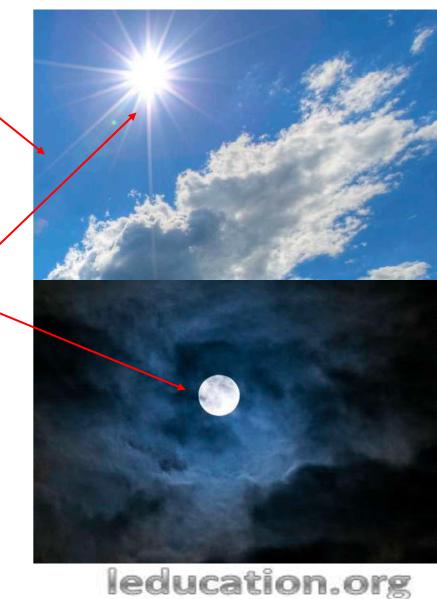
Demonstration 1

Lie ucation Color Constancy (adaptation)

- Our color vision is compromised in the most central field of view
 - Lack of S cones
 - Macular pigment
- We use surrounding information and information about the light source to calculate a perceived color
- Blue colored sky is important to making colder lights appear warmer
- Nature is nominally 6500K
 - Nothing is actually 6500K
 - A gradient of colors warmer than 5000K and colder than 6500K

This is important to shifting the preference curve

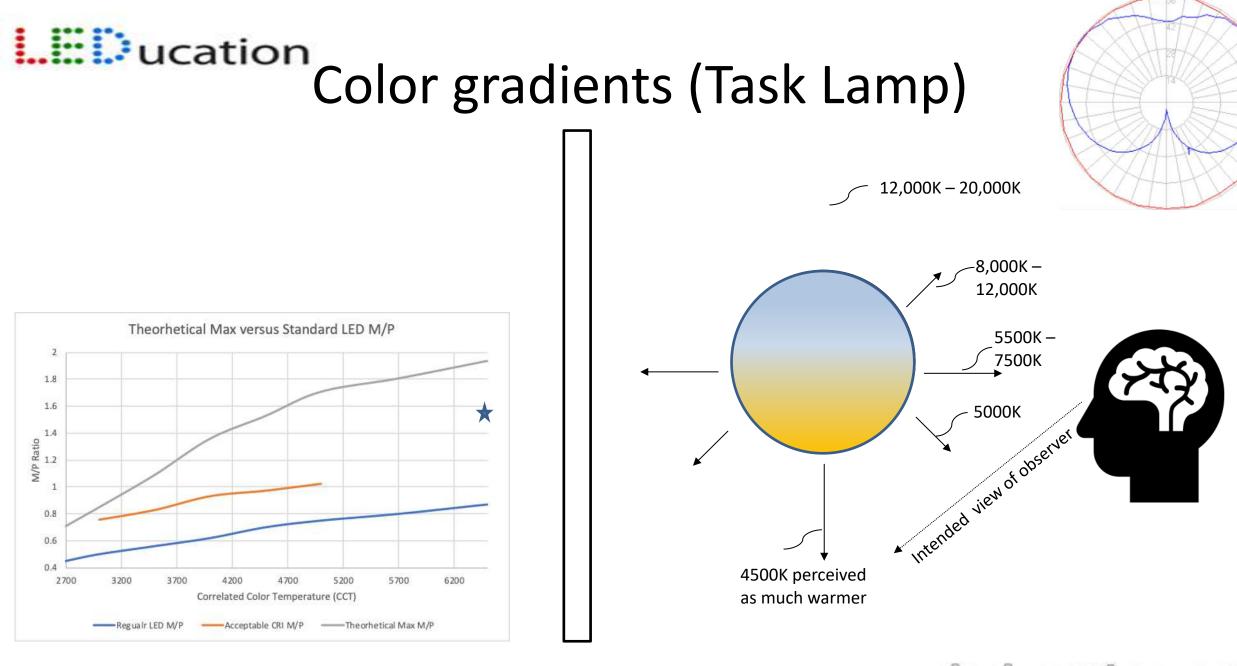
Which is warmer?



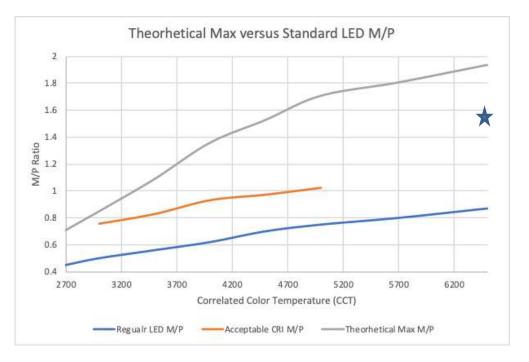


Demonstration that is WAY better in person





Color gradients (Task Lamp)





Color gradients (Task Lamp)

- 6500K directed at the eye (1.5 m/p ratio)
 - 3 vertical lumens for 1 horizontal lumens
- Provides 200 melanopic lux when placed next to a monitor
 - Takes all the design work out of meeting WELL
- Biophilic component
- Individualized control



Final recap



Health and Wellness lighting:

- We're in enough agreement in order to really get started
- Think about spectrum and color together
 - 490nm peak during the daytime
 - Use coolest acceptable CCT for maximum benefit (note: full agreement at 3500K)
 - 450nm peak at night
 - Use warmest acceptable CCT for maximum benefit
- Standard (not spectrally optimized) LED can achieve daytime requirements, but it will come at the cost of energy and comfort
- Spectrally optimized solutions can provide an energy efficient and comfortable daytime environment
- Luminous pendants can increase the vertical lux compared to traditional light sources

- Color separation can take circadian lighting to the next level
- Task lighting is going to take a new evolution

Catnap Mural by Michael Sommers Location: Carlsbad, CA

Change is the essence of life. Surrender who you are for what you could become.

~ Reinhold Niebuhr





This concludes The American Institute of Architects Continuing Education Systems Course



