LEDucation
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Specifying outdoor lighting that enables decarbonization and minimizes light pollution doesn't have to be a headache

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

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Learning Objectives

At the end of this course, participants will:

1. Participants will gain a deep understanding of the negative impacts of light pollution and how to combat it.
2. learn of a series of resources for specifying non-white light fixtures
3. Understand the difficulties in specifying non-white light and will be given a specification framework that can be used immediately
4. Participants will be abreast of the latest standards development work (specifically ANSI C78.377) that is in the pipeline.

Problem 1 :

Light pollution is bad, and is getting worse

PROBLEM: ANTHROPOGENIC LIGHT AT NIGHT (ALAN) IS INCREASING YEAR-OVER-YEAR

- Global satellite data indicates ALAN has increased by at least 2% each year over 25 years
- Citizen science data indicates that ALAN is growing by 9.6% each year over 10 years

ALAN IS CAUSING NEGATIVE ECOLOGICAL IMPACTS

- ALAN is disrupting nocturnal behavior of a variety of insects, contributing to the insect apocalypse
- ALAN is interfering with migratory behavior of bats and birds on local, regional and macroscales
- ALAN disorients sea turtle hatchlings leading to increased mortality
- ALAN causes circadian disruptions in plants and animals
- ALAN increases some pathogenic risks

ALAN CONTRIBUTES TO SYSTEMIC INEQUITIES

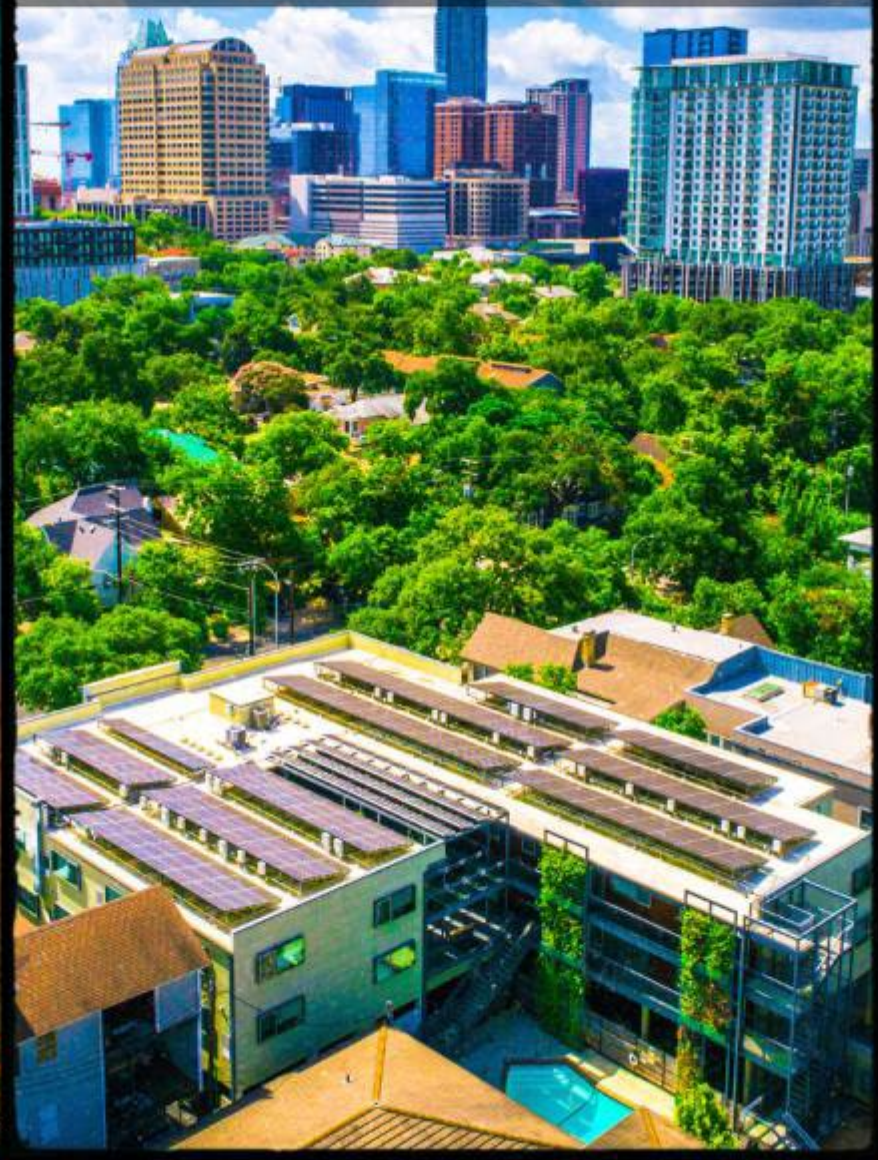
When dark sky gets brought up, it's always brought up as an environmental issue, not as an equity one. No one is talking about who has access to the night sky. It's just that there is a night sky to be seen because that's what's good for the planet.

Lauren Dandridge

Outdoor lighting performance impacts decarbonization efforts

energy efficiency

demand flexibility



electrification

Problem 2 :

NWL specification is messy


WHICH "BLUE" LIGHT
DO I AVOID?

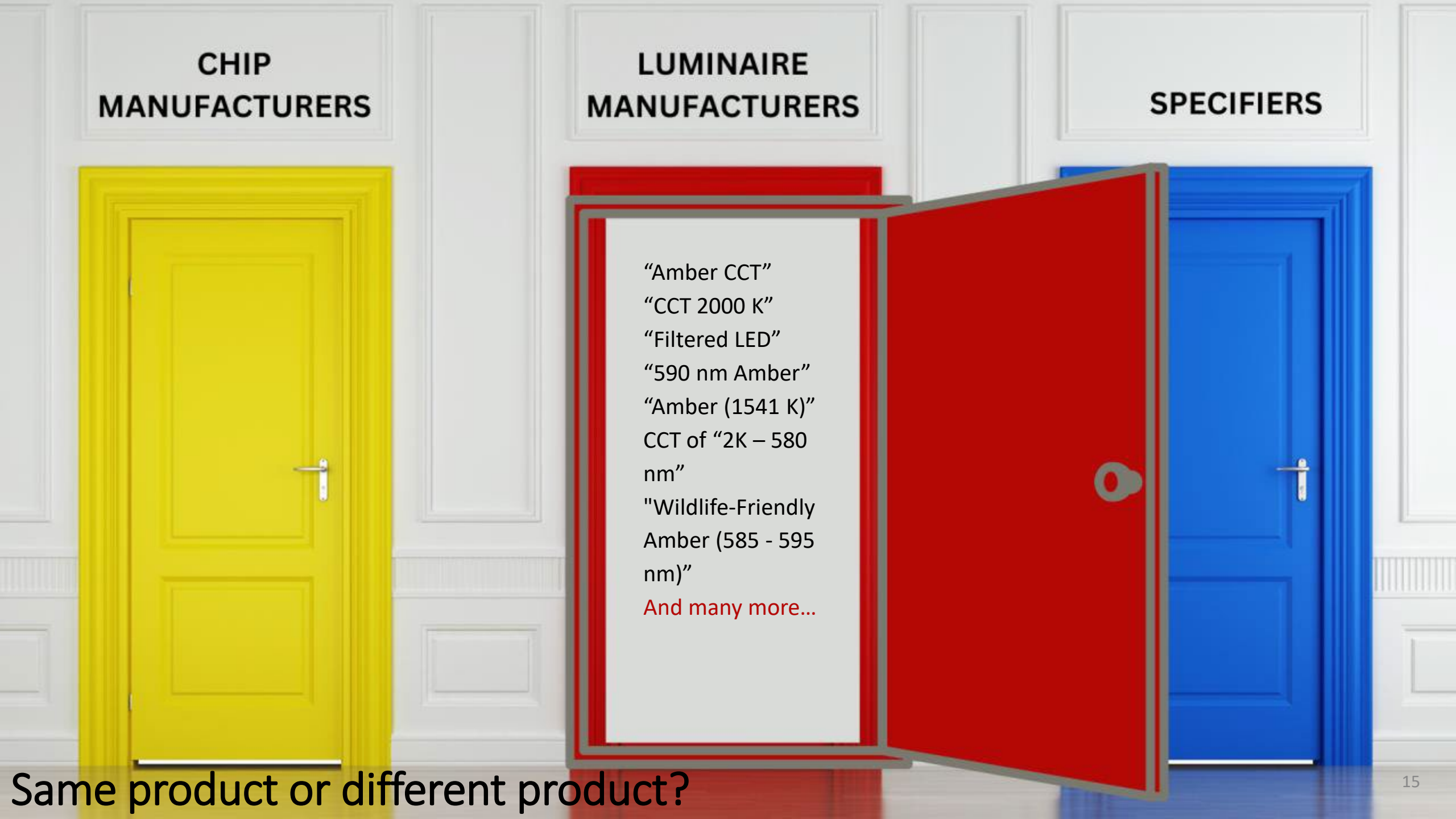

CHIP MANUFACTURERS
LUMINAIRE MANUFACTURERS
SPECIFIERS

There is no standard for NWL chips for general illumination

There is no standard for NWL luminaires for general illumination

Photo by Hans-Peter Gauster on Unsplash

Same product or different product?



Same product or different product?

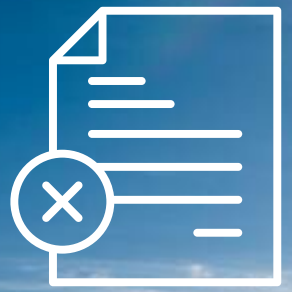
Same product or different product?

It's not easy to incorporate "amber" luminaires into design

less common

Minimum qty

Longer lead times



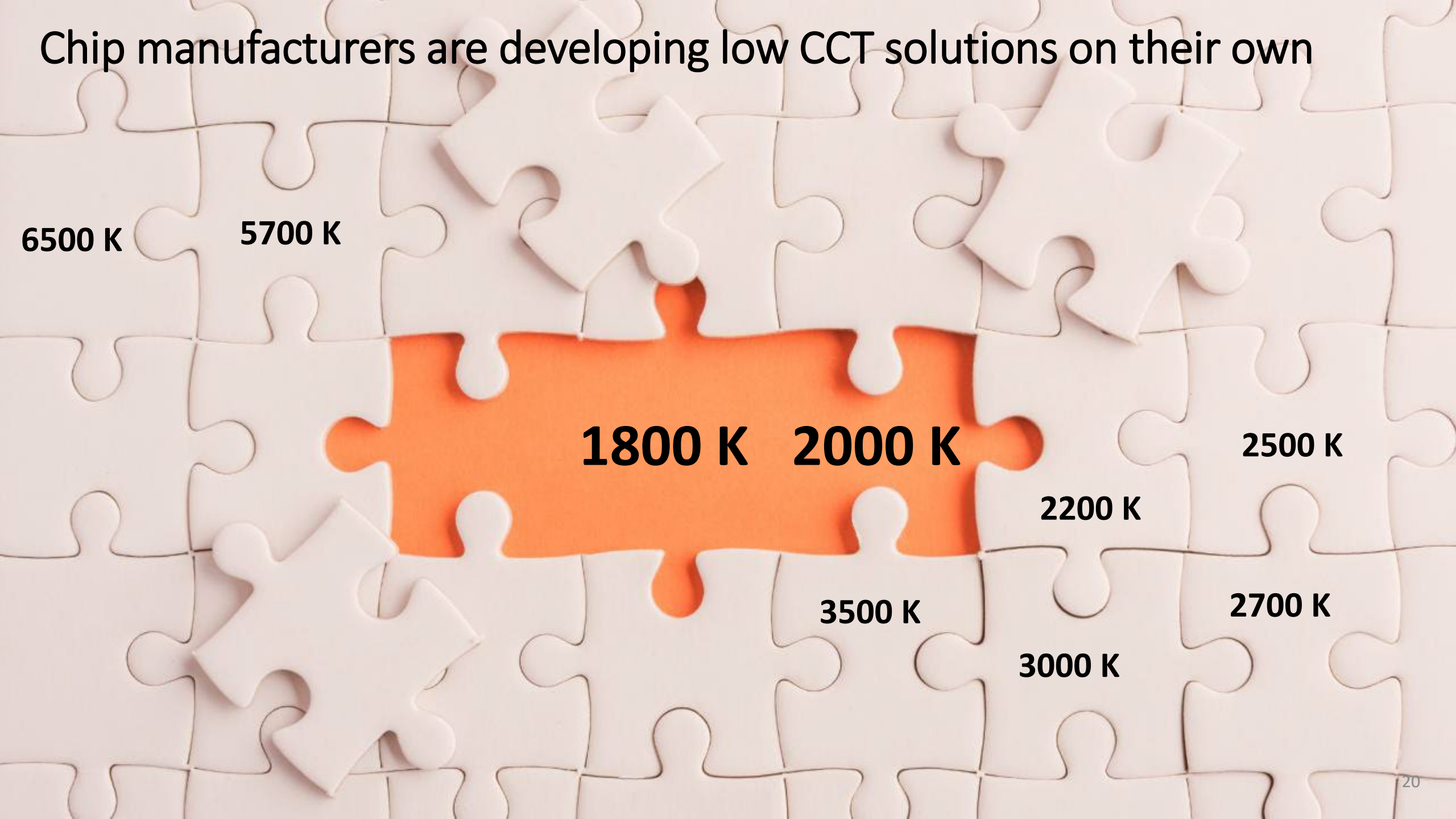
Ineligible for incentives

Problem 3 :

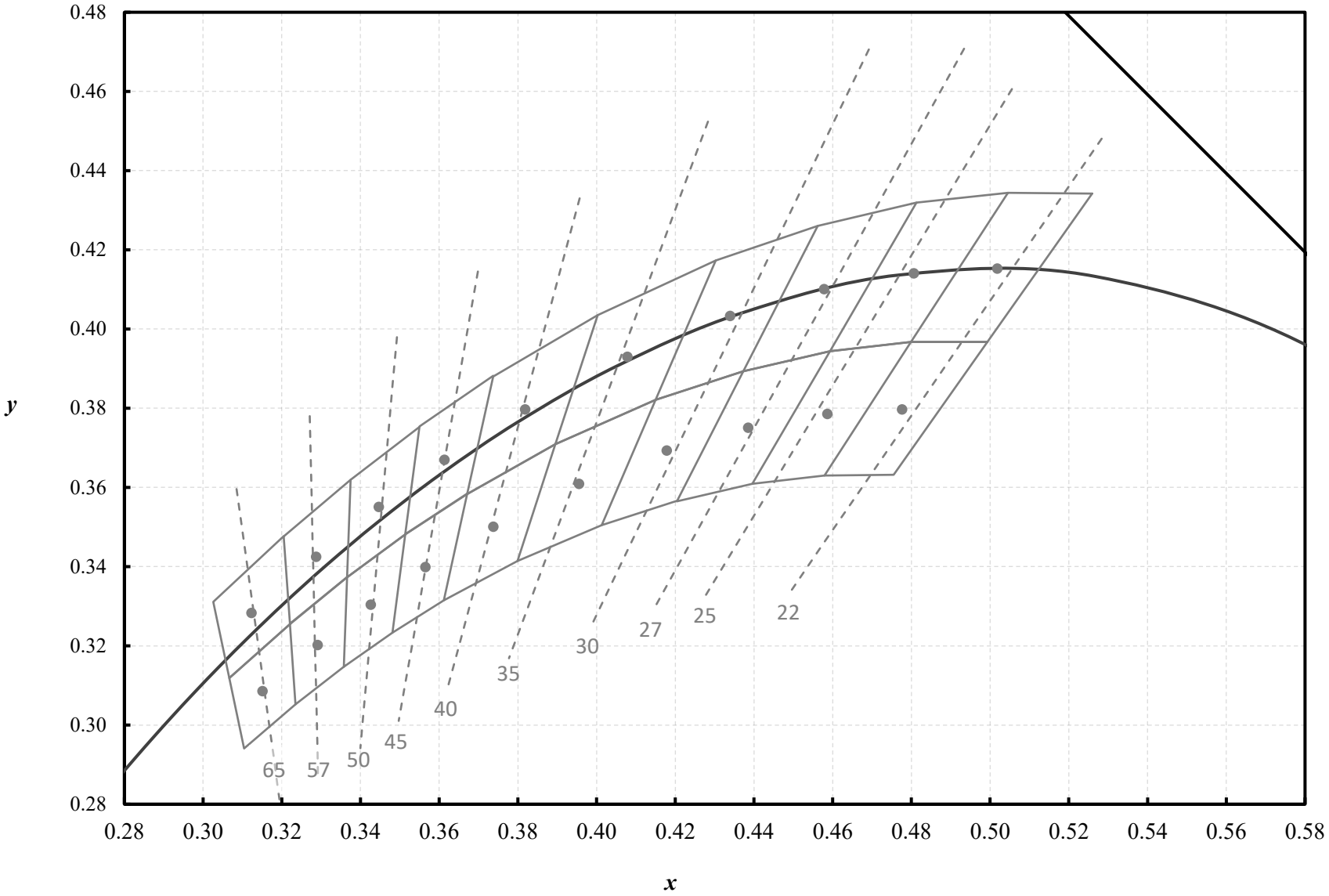
Lighting products are out-pacing standards

There are no simple naming conventions

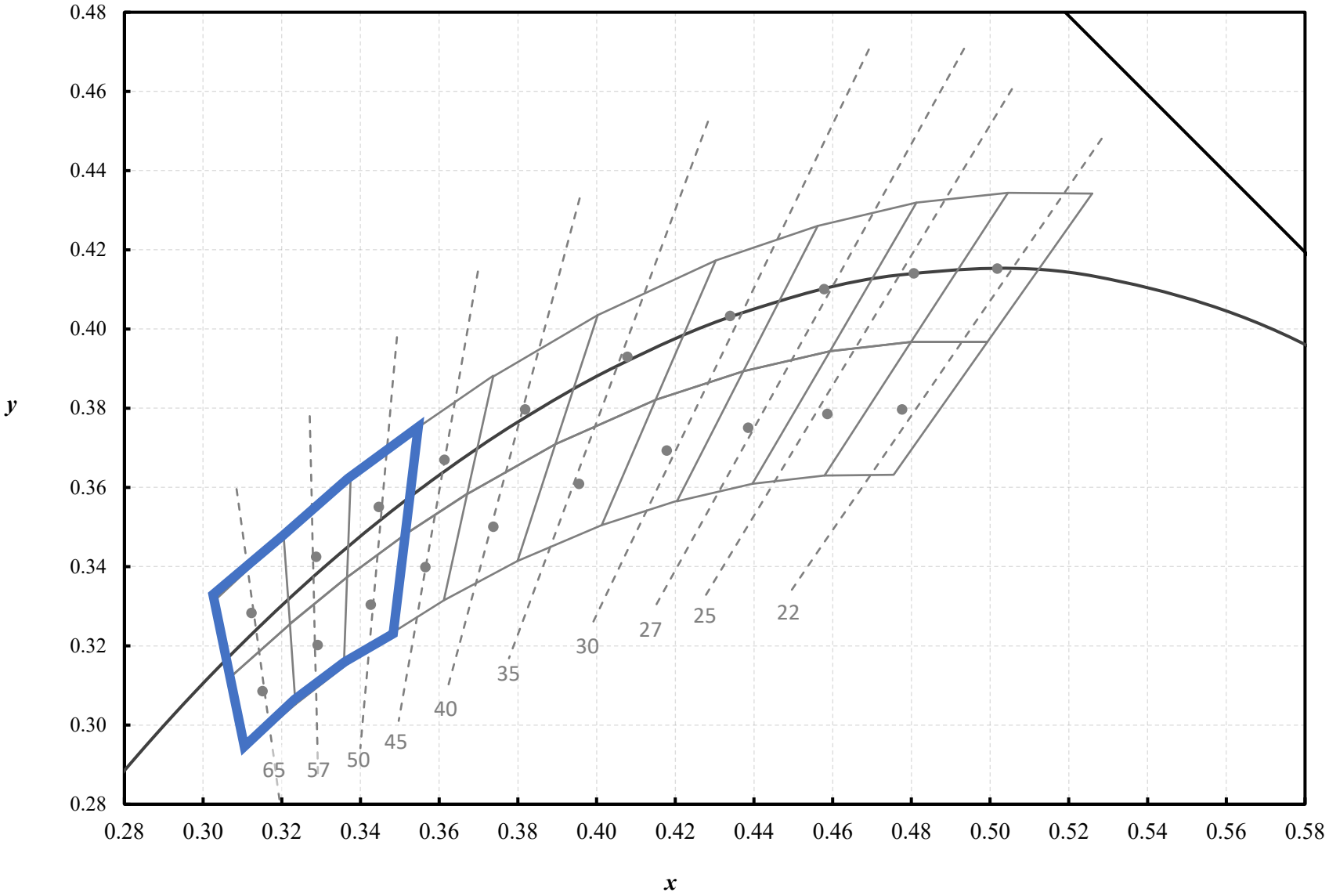
Chip manufacturers are developing low CCT solutions on their own

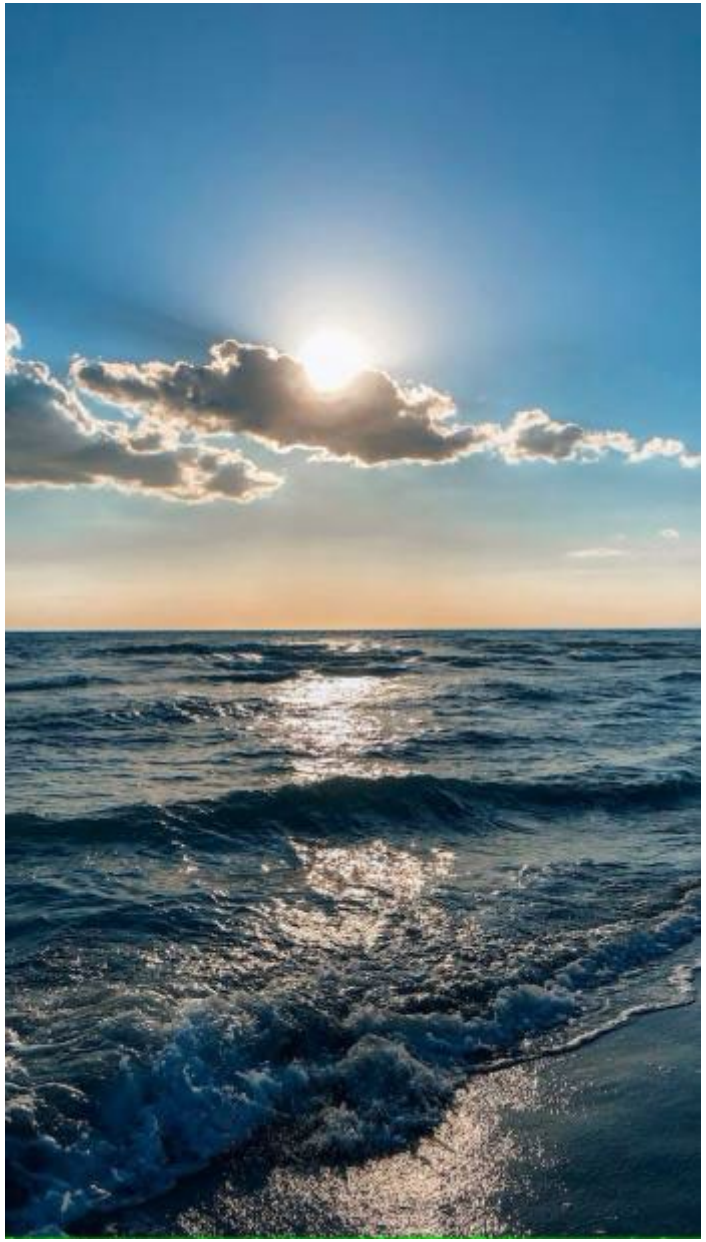


Existing Standards: ANSI C78.377 CCT Quadrangles

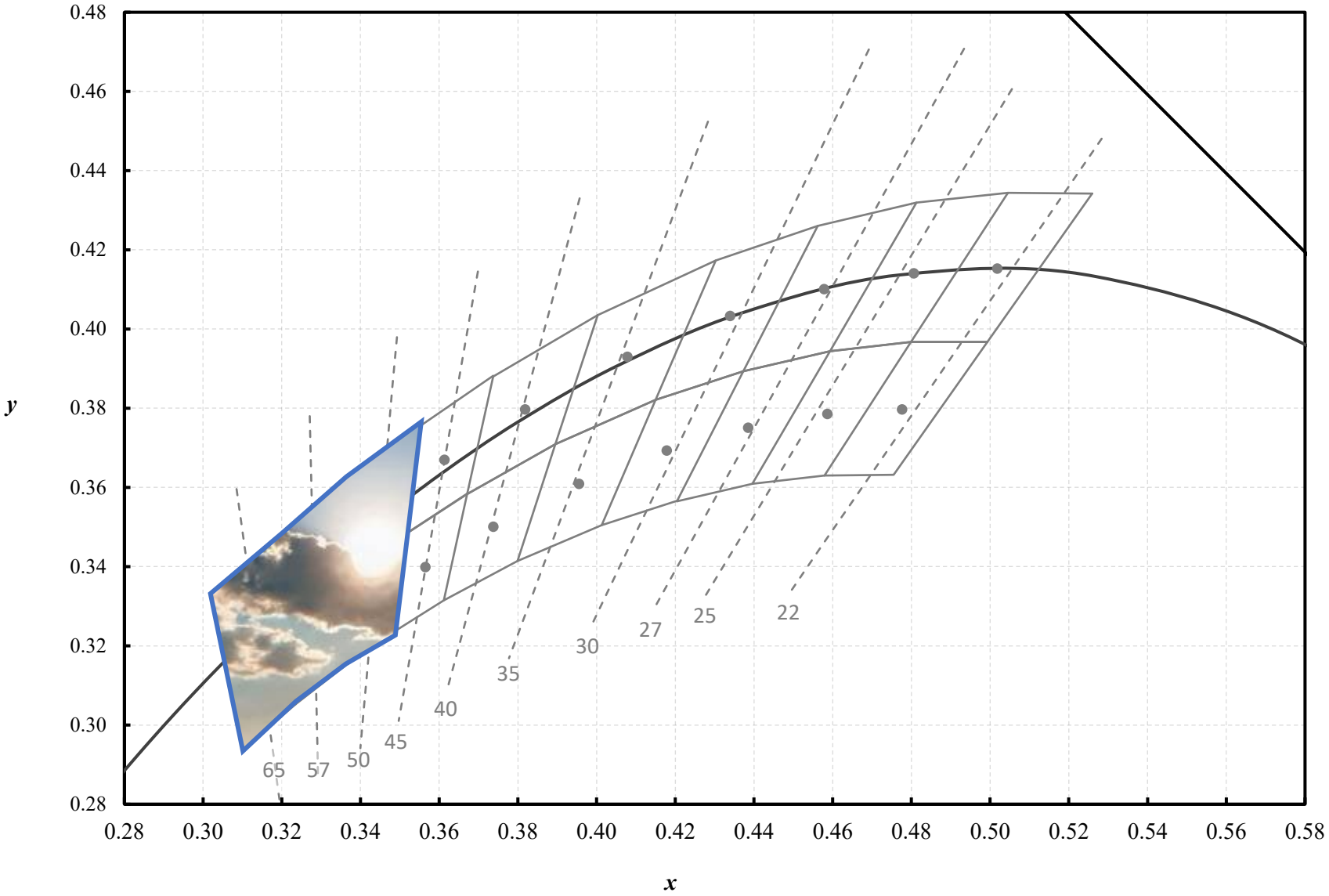


Existing Standards: ANSI C78.377 CCT Quadrangles

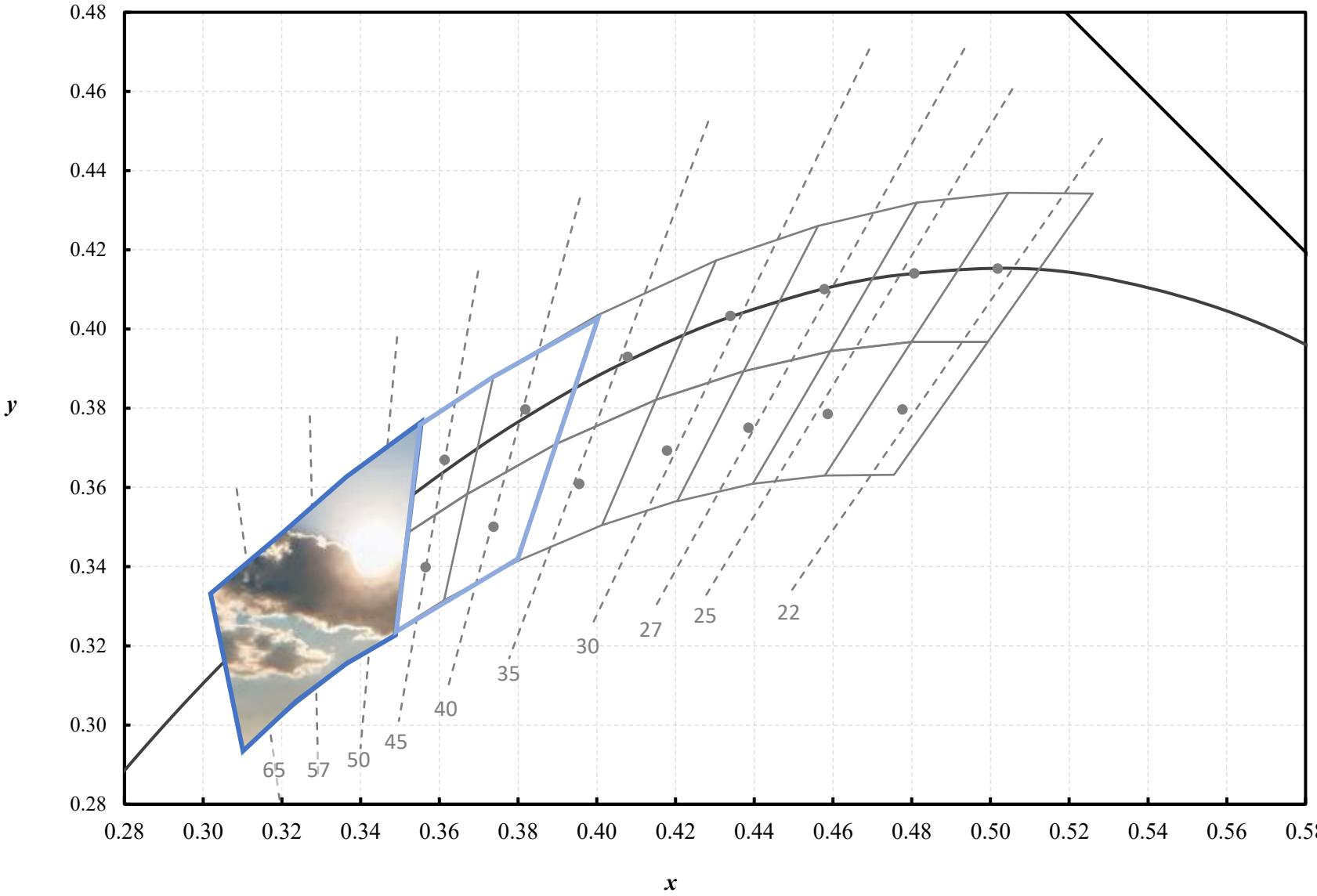




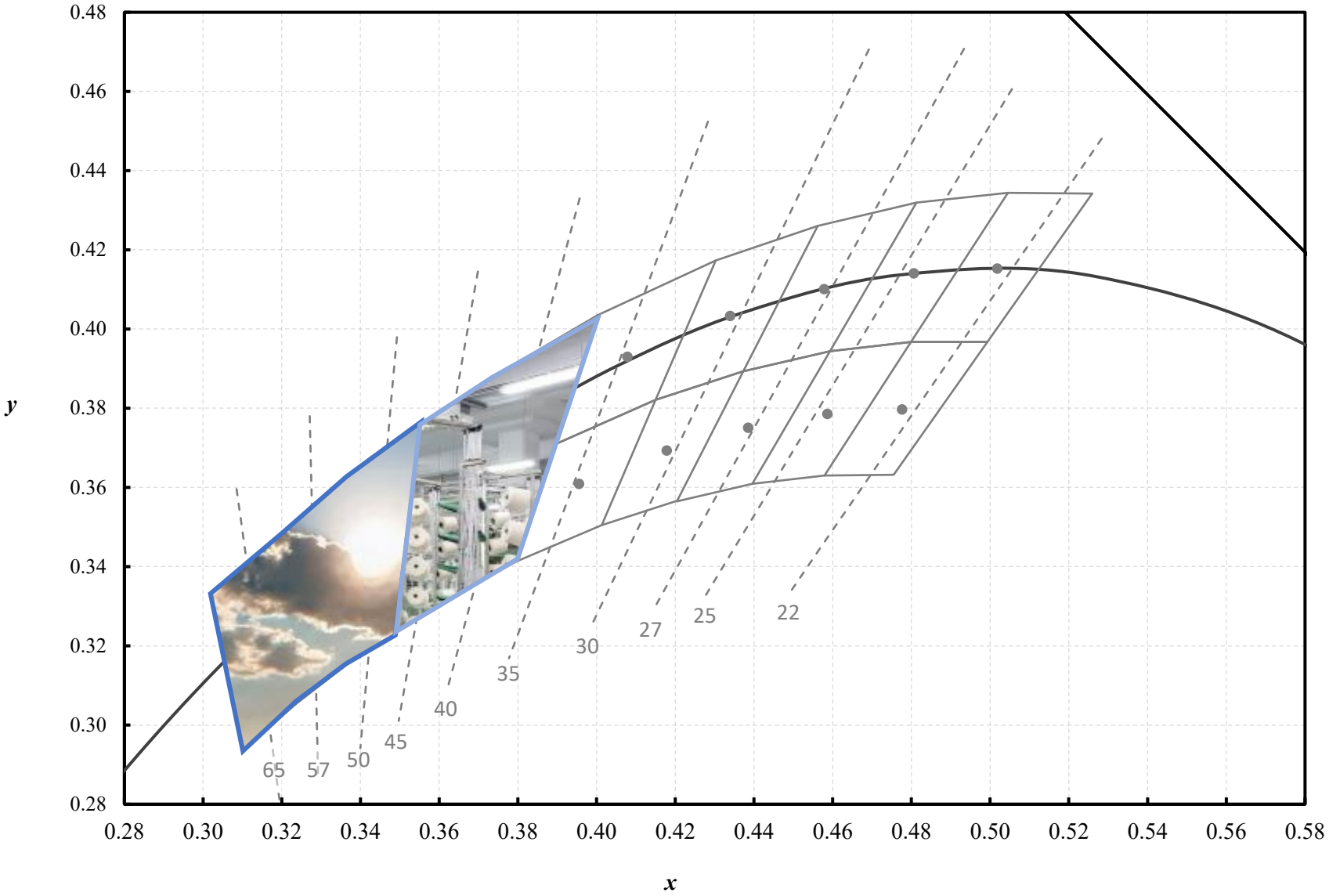
Existing Standards: ANSI C78.377 CCT Quadrangles



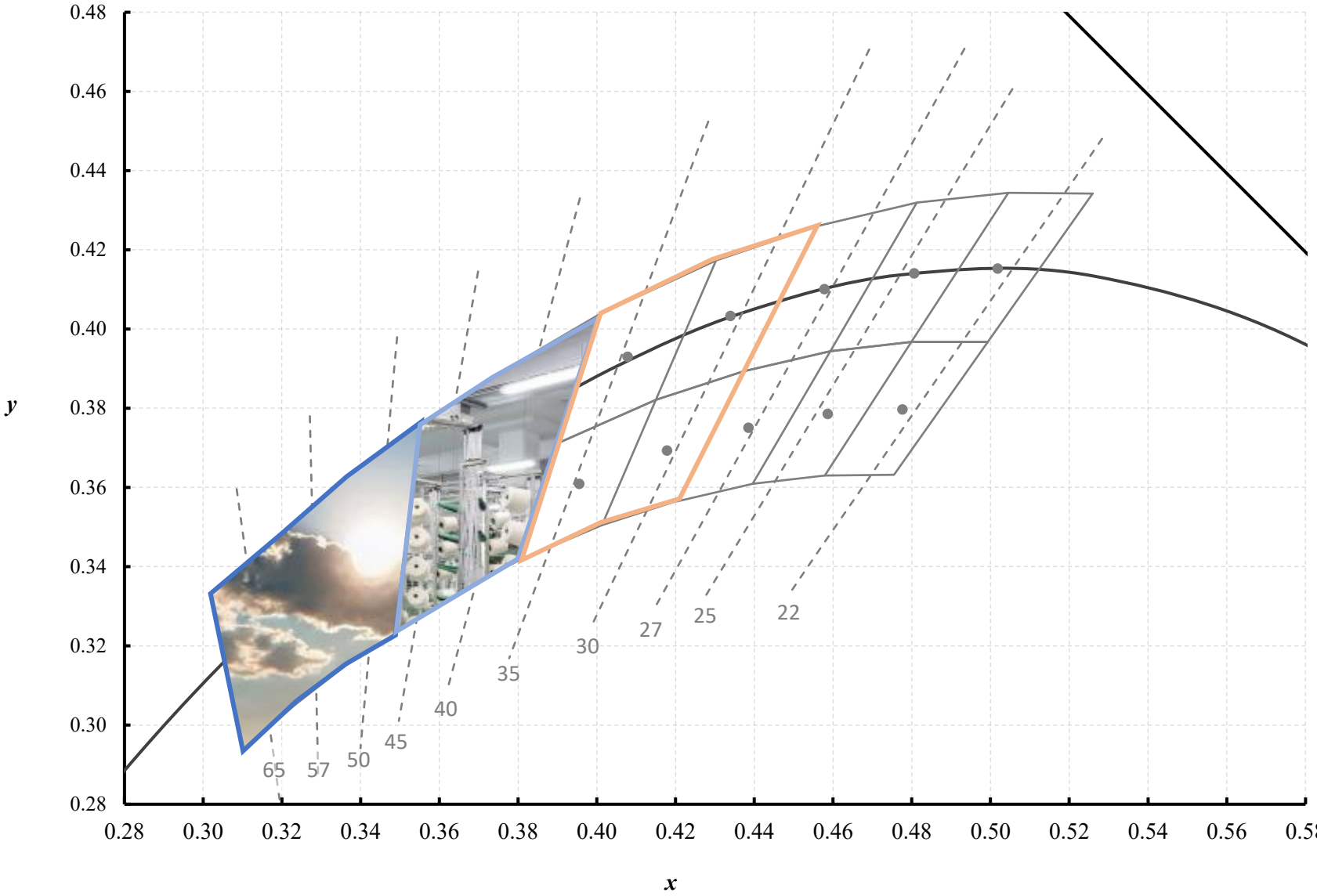
Existing Standards: ANSI C78.377 CCT Quadrangles



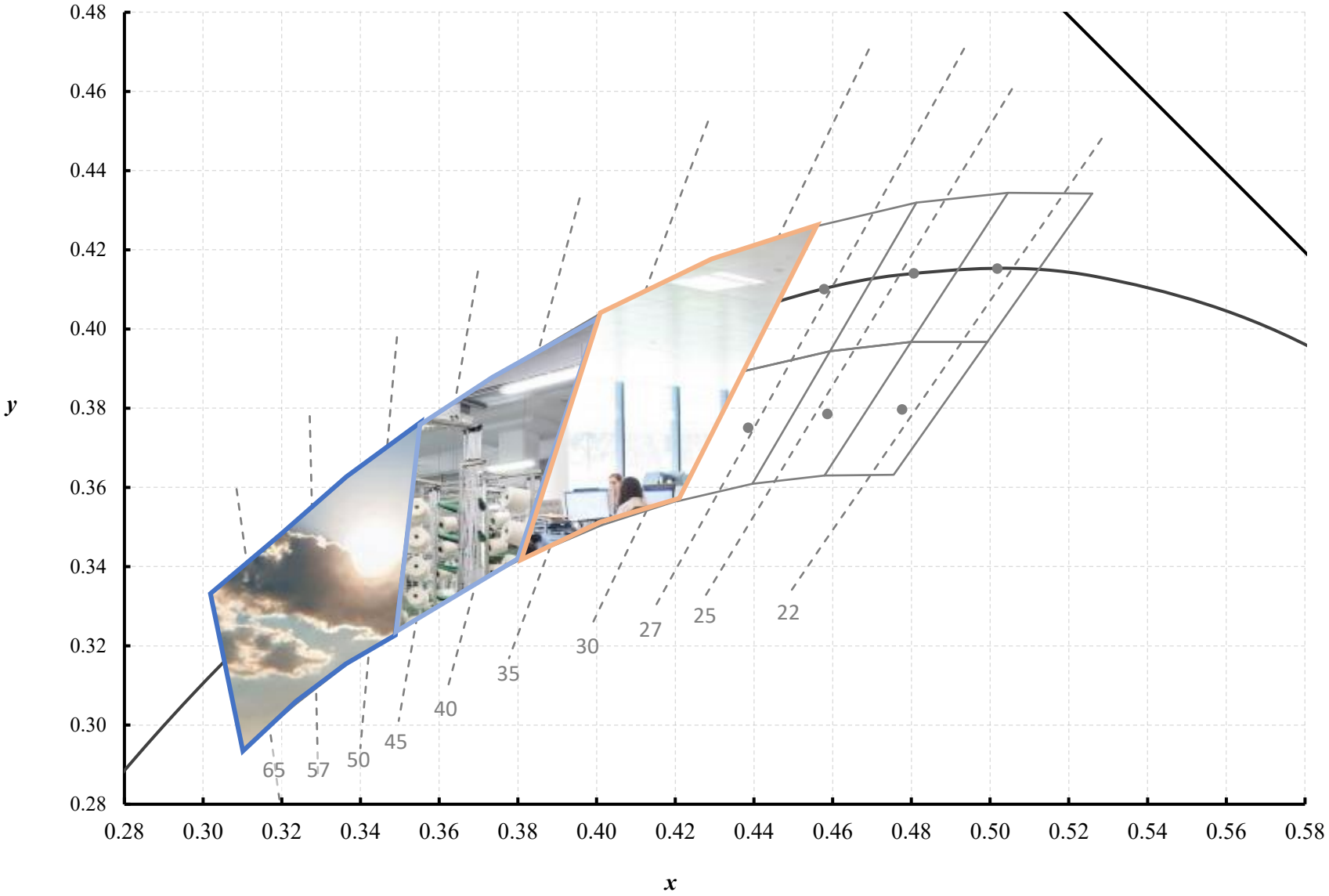
Existing Standards: ANSI C78.377 CCT Quadrangles



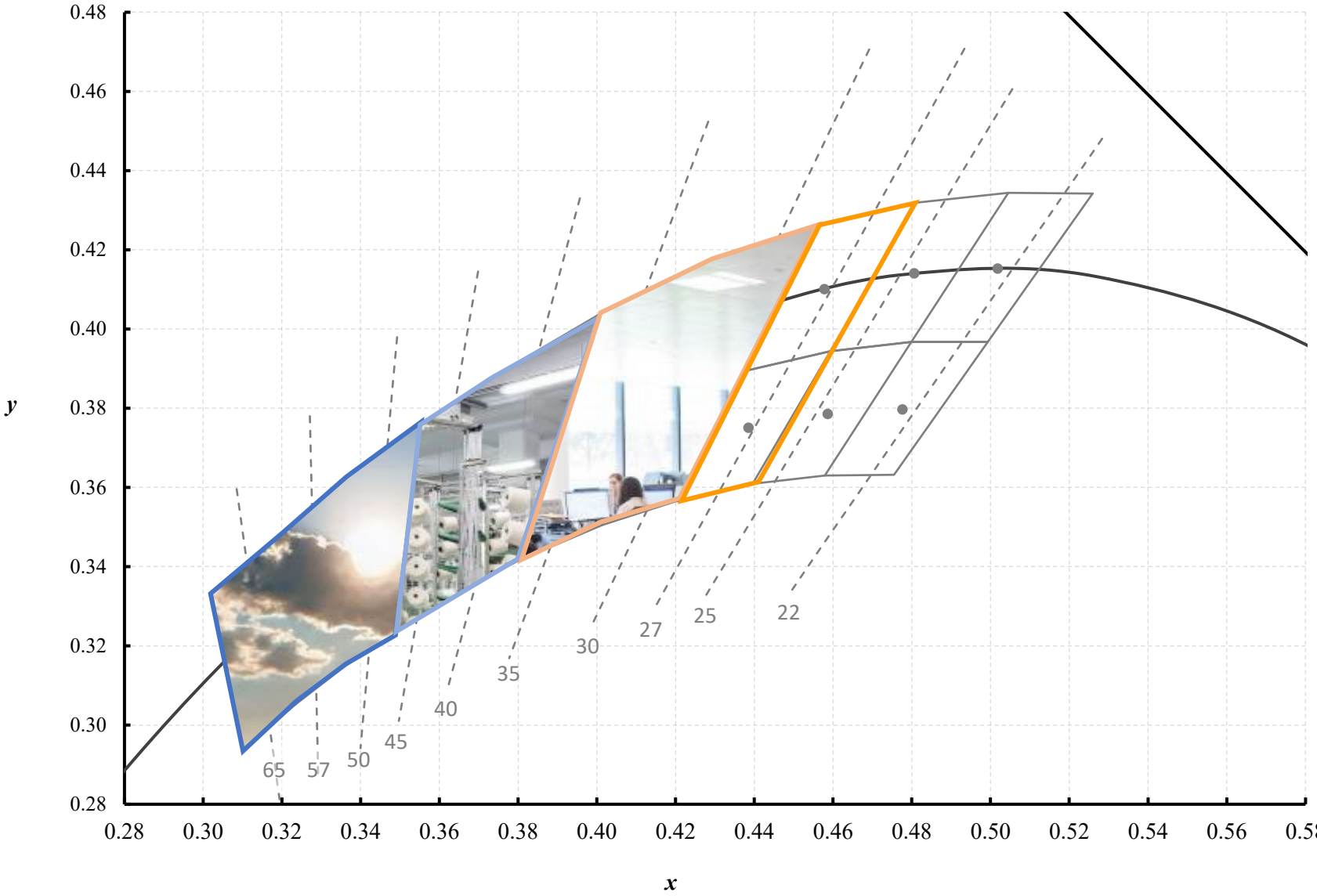
Existing Standards: ANSI C78.377 CCT Quadrangles



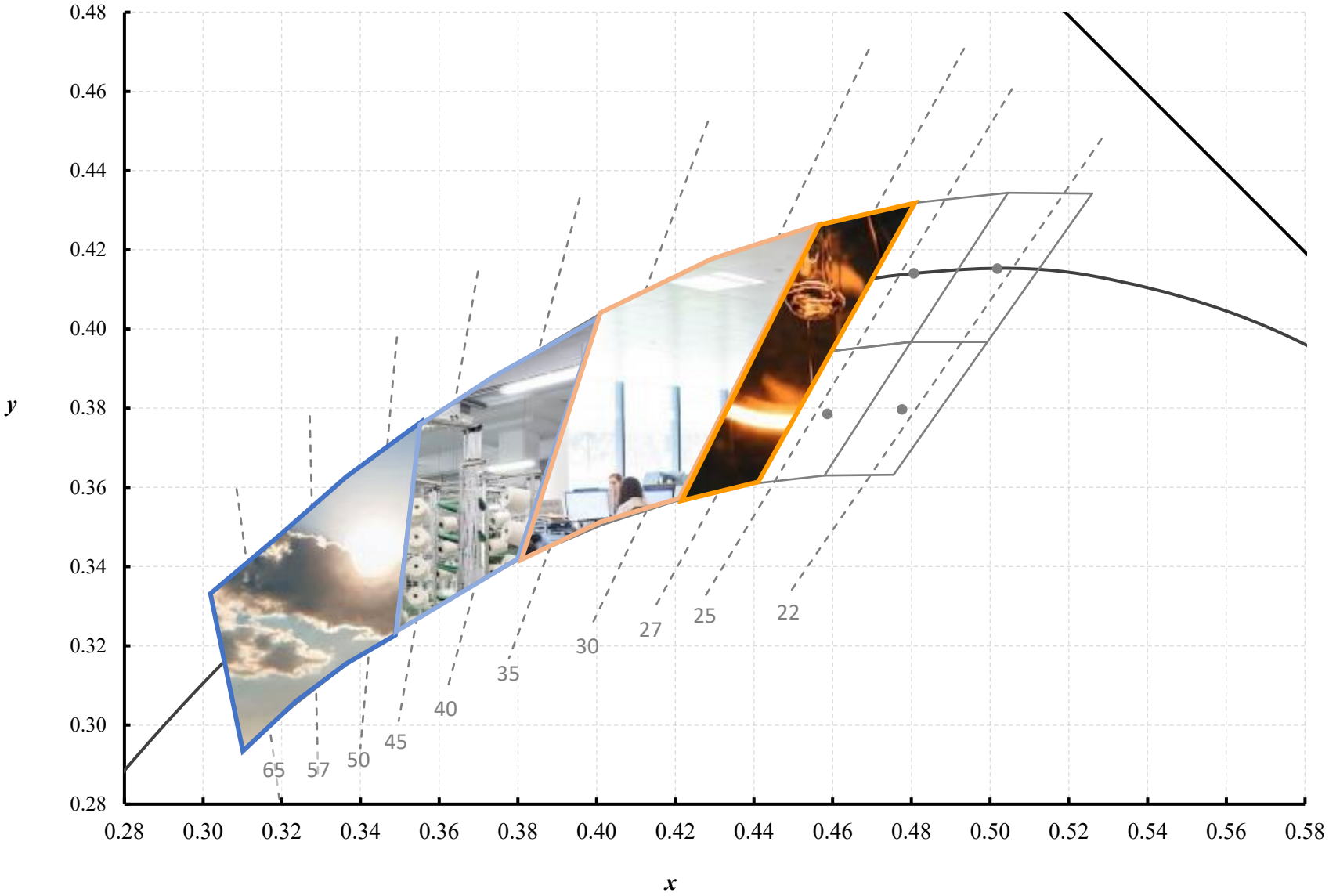
Existing Standards: ANSI C78.377 CCT Quadrangles



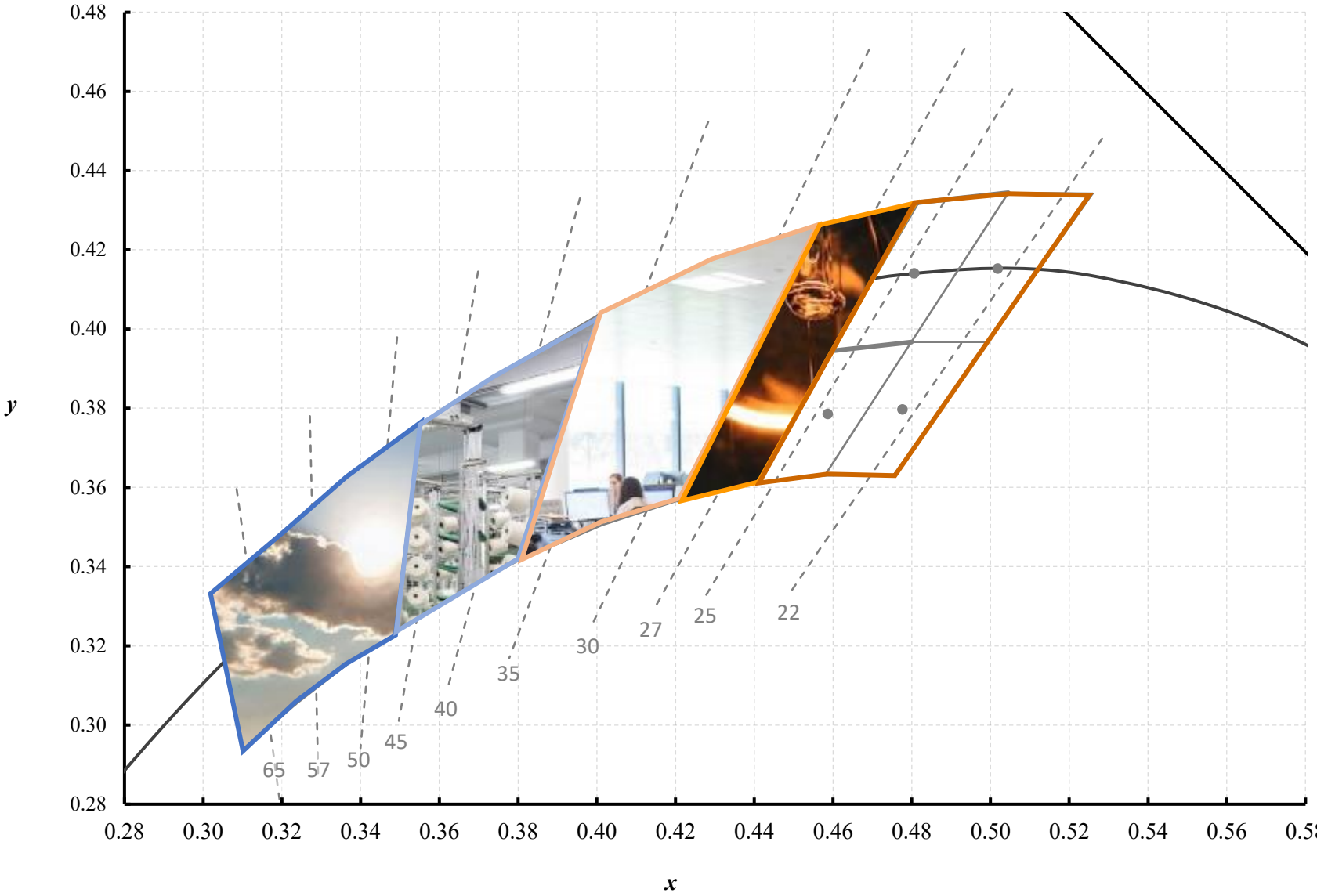
Existing Standards: ANSI C78.377 CCT Quadrangles



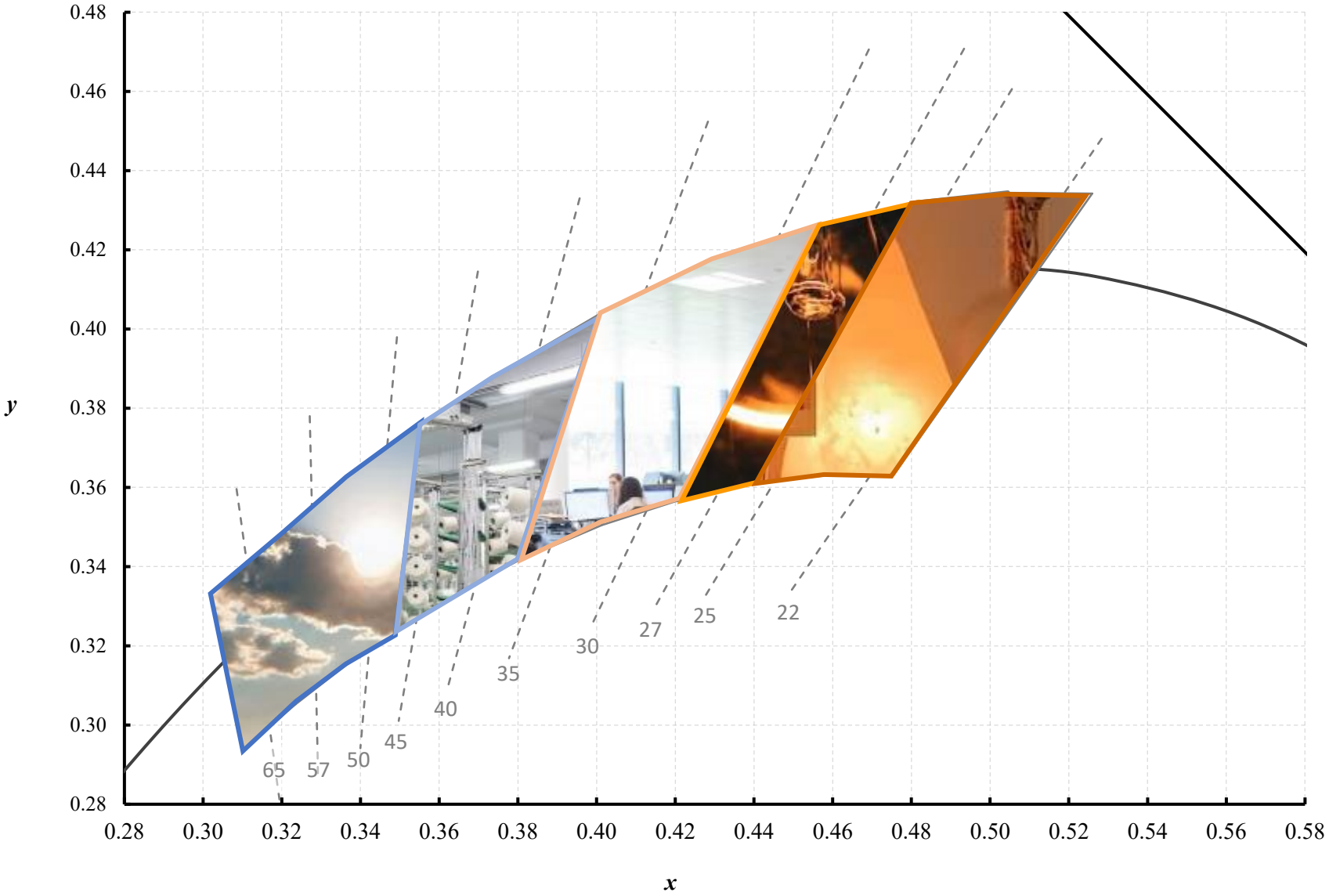
Existing Standards: ANSI C78.377 CCT Quadrangles



Existing Standards: ANSI C78.377 CCT Quadrangles



Existing Standards: ANSI C78.377 CCT Quadrangles



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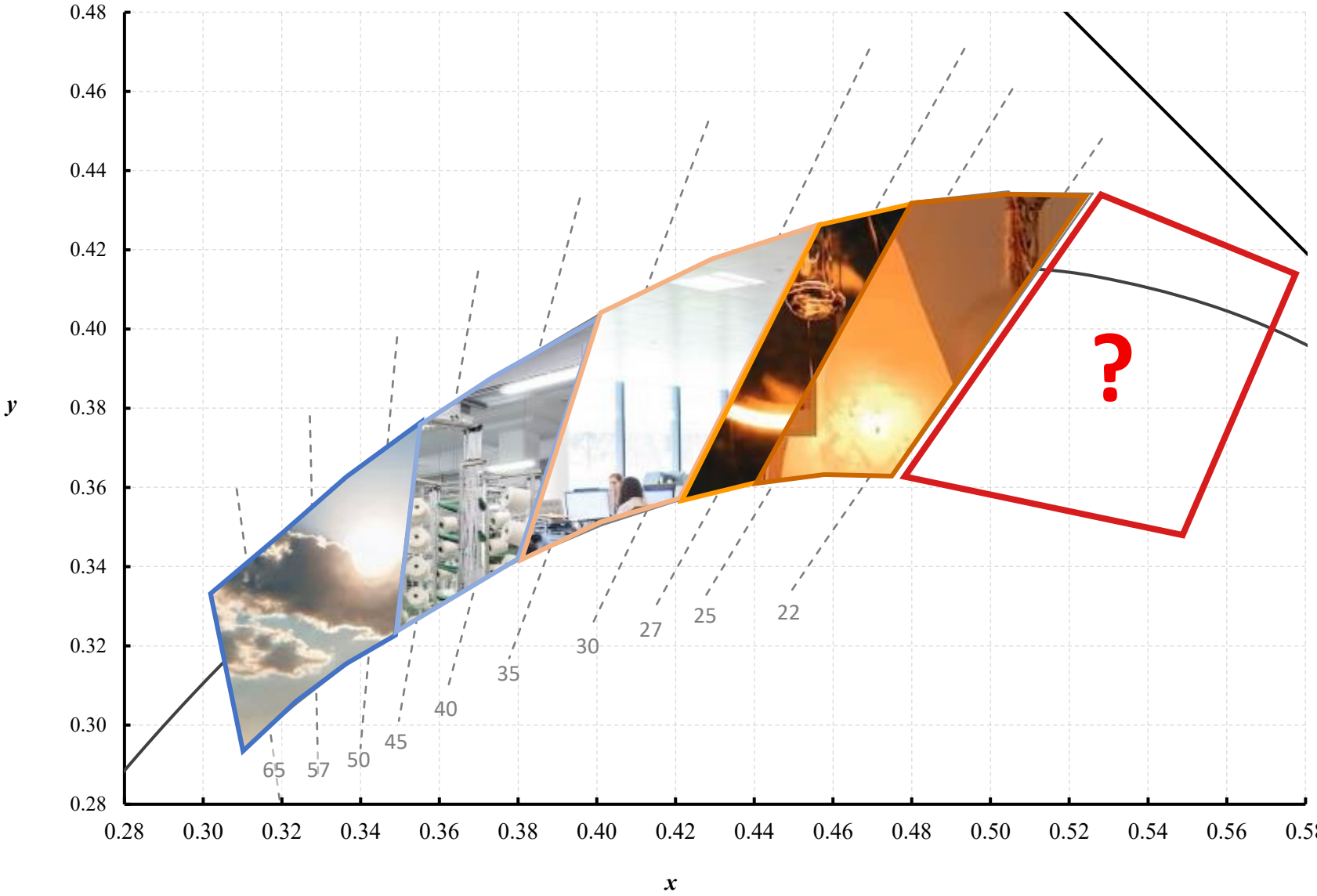


https://led-ld.nichia.co.jp/img/led/lighting_lowcct_1_e.png

Solution 1 :

Develop new quadrangles to inform standards

Regulations are occurring in the absence of standards

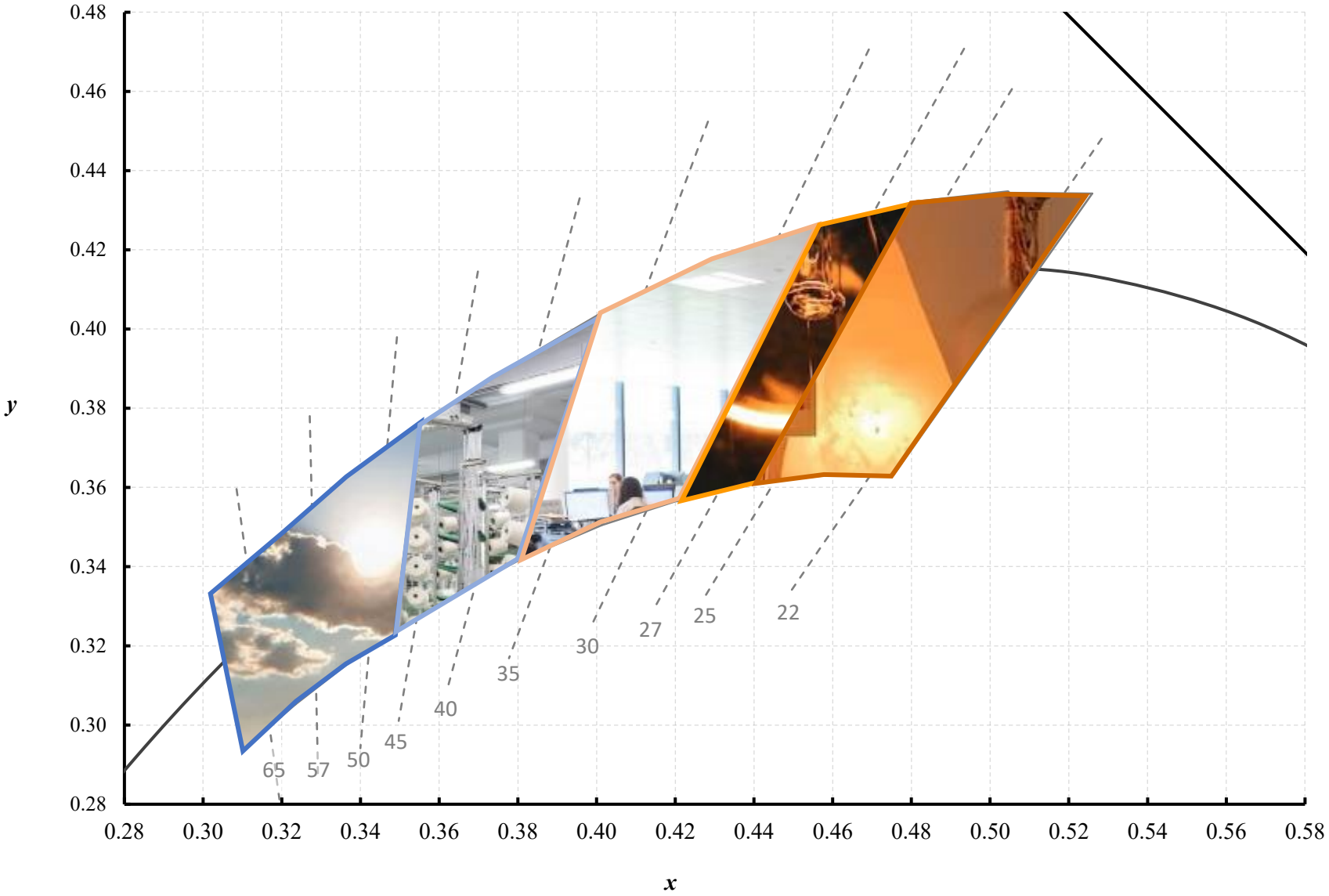
Increasing light pollution and awareness

Non-lighting experts

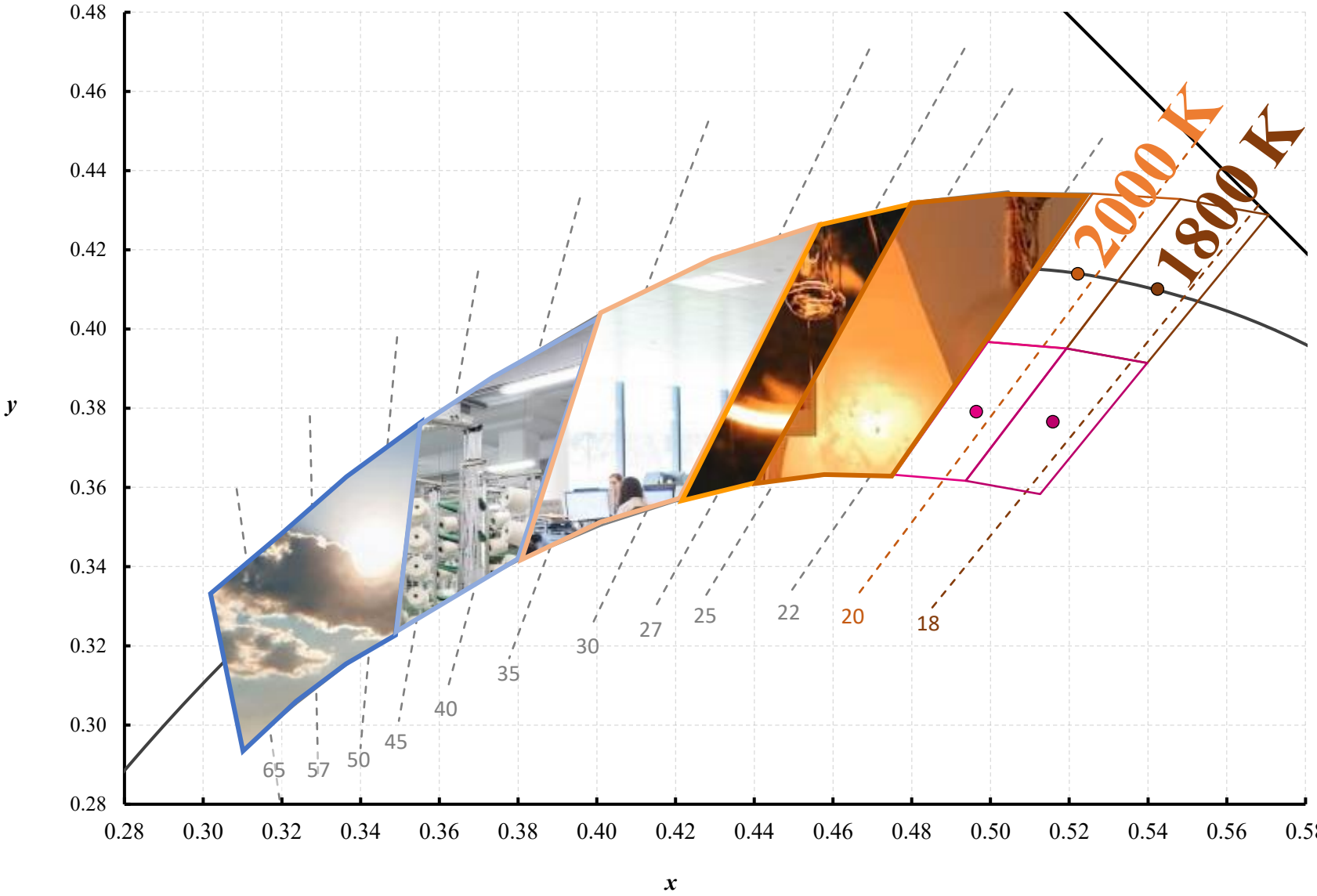
Outdated/imprecise info

Range of applications (environmentally sensitive, close to observatory, dark sky community)

Existing Standards: ANSI C78.377 CCT Quadrangles



Existing Standards: ANSI C78.377 CCT Quadrangles



Esposito T, Radetsky L. 2023. Specifying non-white light sources in outdoor applications to reduce light pollution. LEUKOS.

https://led-ld.nichia.co.jp/img/led/lighting_lowcct_1_e.png

Develop new quadrangles: 2000 K and 1800 K

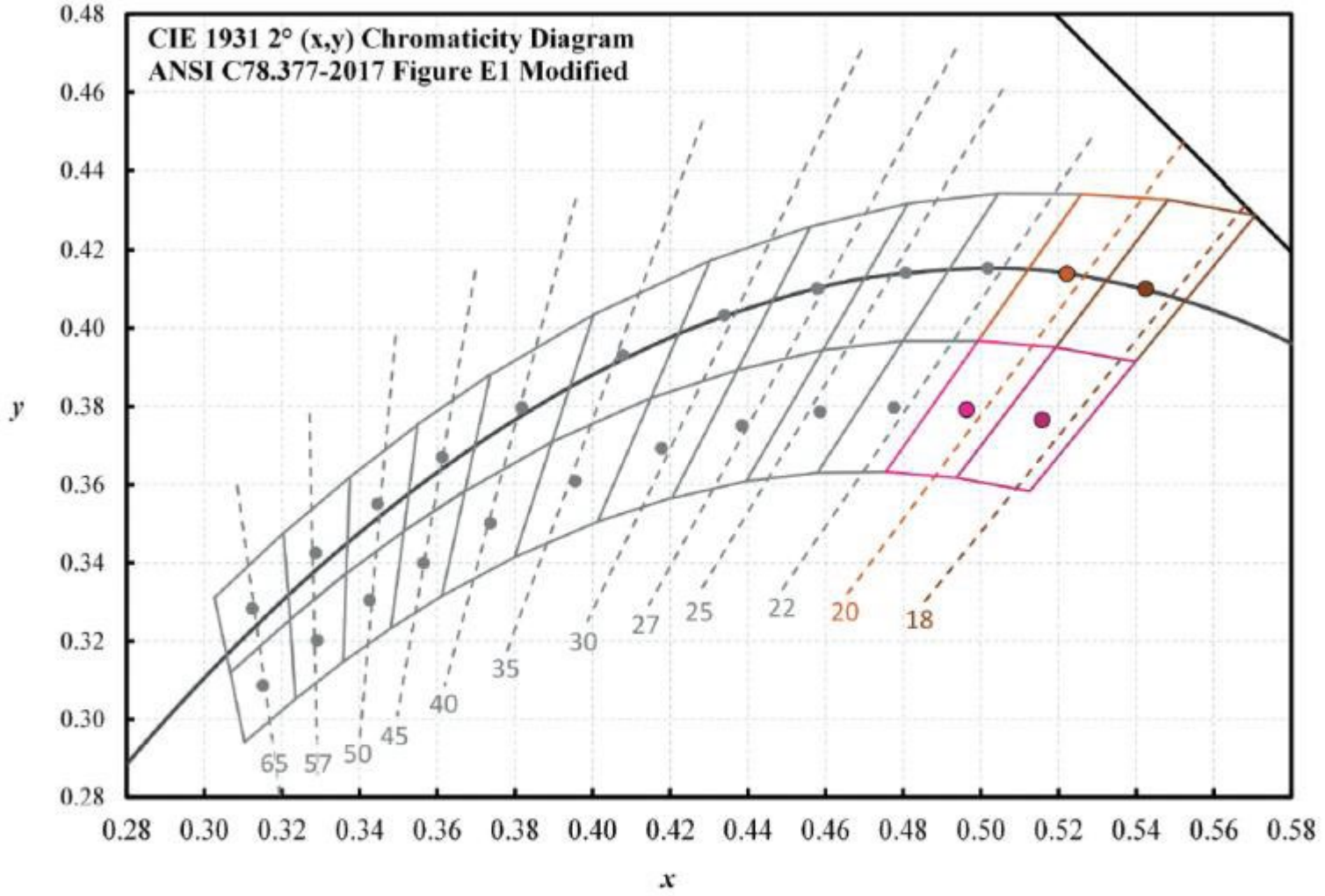


Fig. 2. An enlarged portion of the CIE 1931 *xy* chromaticity diagram. Shown are the proposed *expanded* quadrangles for CCT designations of 2000 K and 1800 K alongside the *basic* and *extended* ANSI C78.377–2017 quadrangles. Number labels indicate the CCT of the nearby iso-CCT line with the trailing zeros removed for clarity (e.g., "20" = "2000 K").

Esposito T, Radetsky L. 2023. Specifying non-white light sources in outdoor applications to reduce light pollution. LEUKOS.

Solution 2 :

Specification framework for NWL sources

Specification structure supports ease of use and reduced light pollution

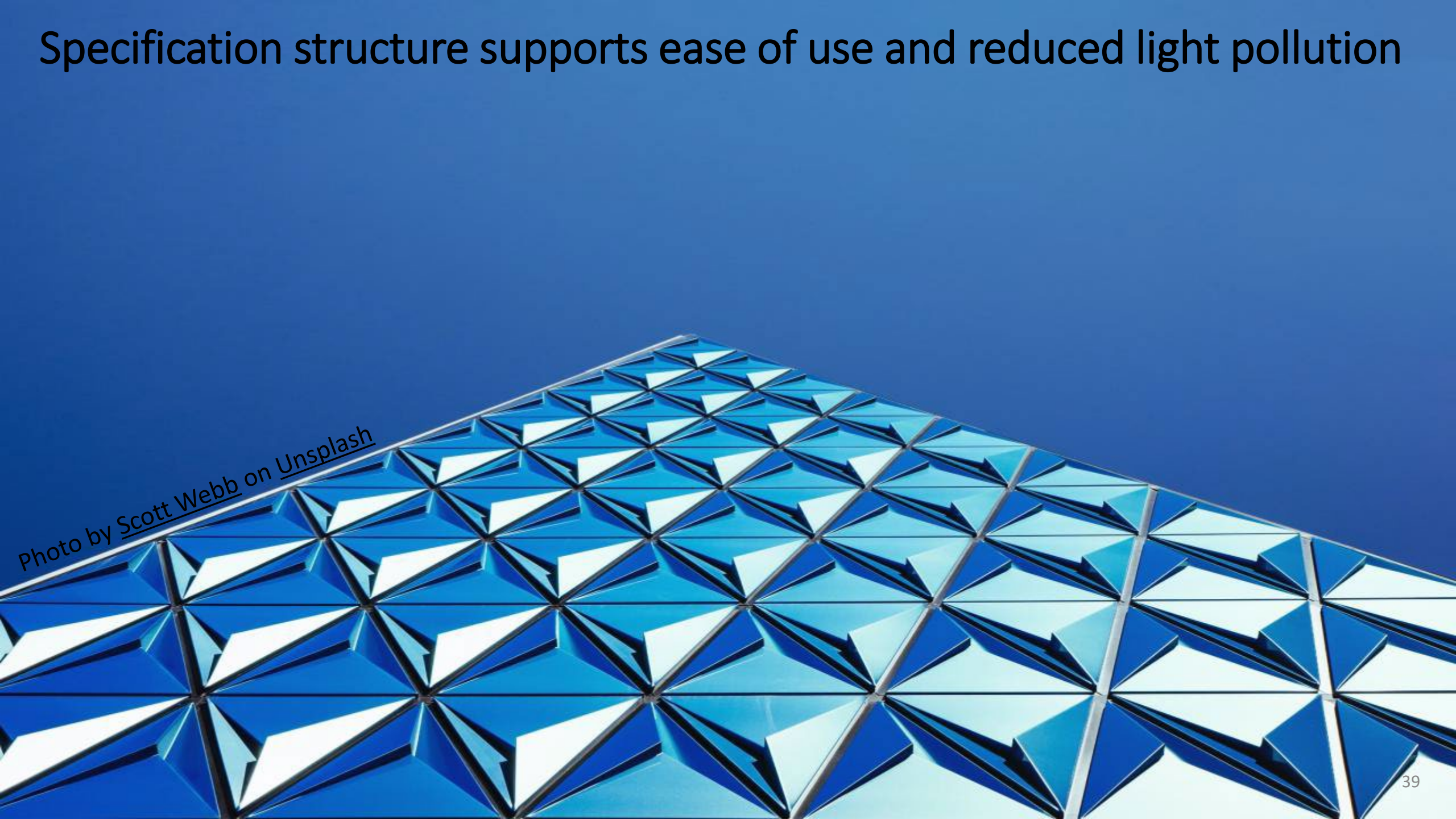
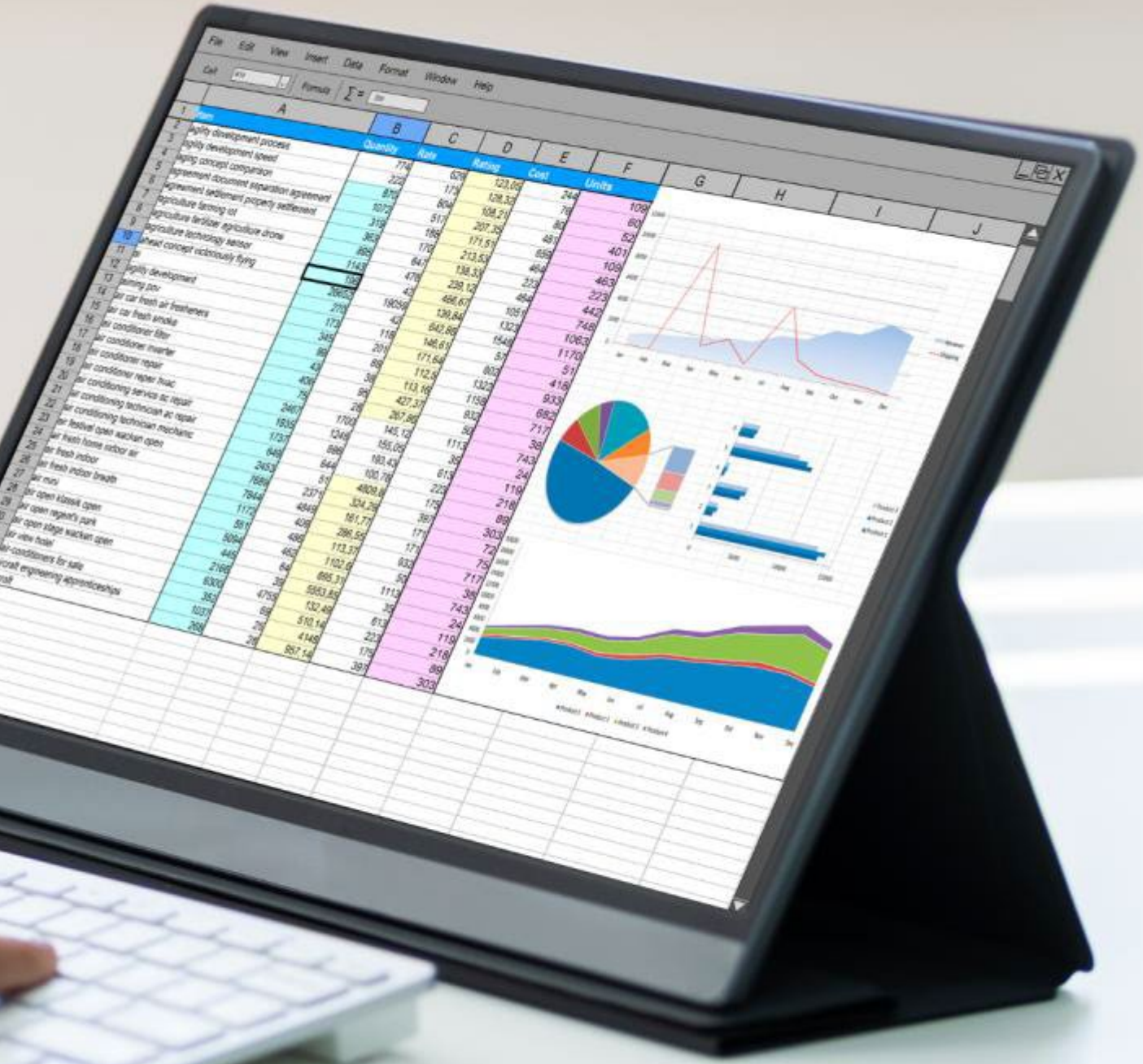


Photo by Scott Webb on Unsplash



Predicting sky glow

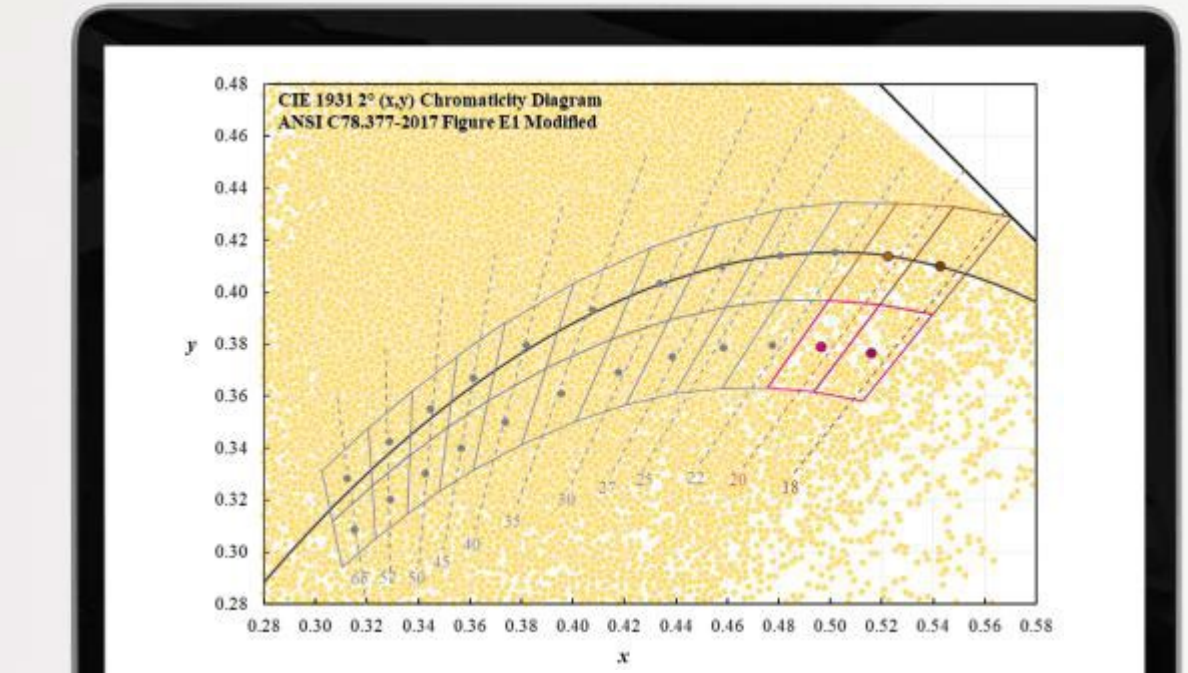
- Compute RSG with PNNL tool
- Set HPS as baseline

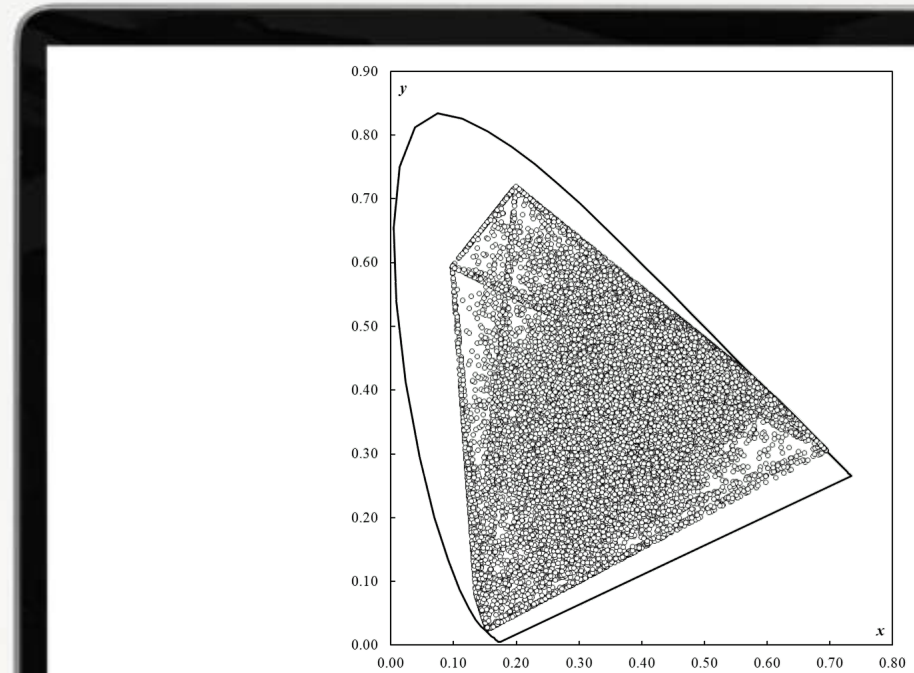
Predicting sky glow: compute RSG

Step 1: Use real LED SPDS to create polychromatic SPDs

Predicting sky glow: compute RSG

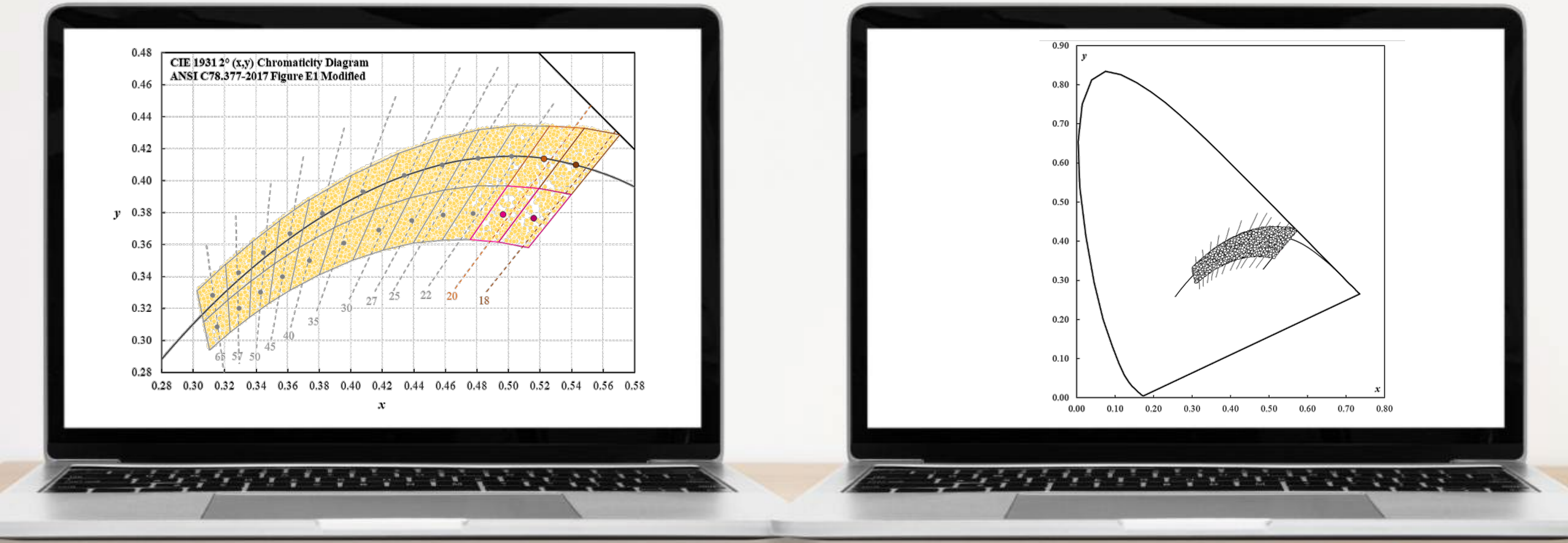
Step 2: Calculate RSG value for each simulated SPD





Predicting sky glow: compute RSG

Step 3: Limit data set to values within ANSI quadrangles and pc-amber/de-amber range



Less blue light results in less sky glow

6500 K
to
4000 K

2.5x – 7.5x

the sky glow relative to
High Pressure Sodium

“6500 K” or “4000 K”

ANSI C78.377-2017

Less blue light results in less sky glow

1.9x – 4.8x

the sky glow relative to
High Pressure Sodium

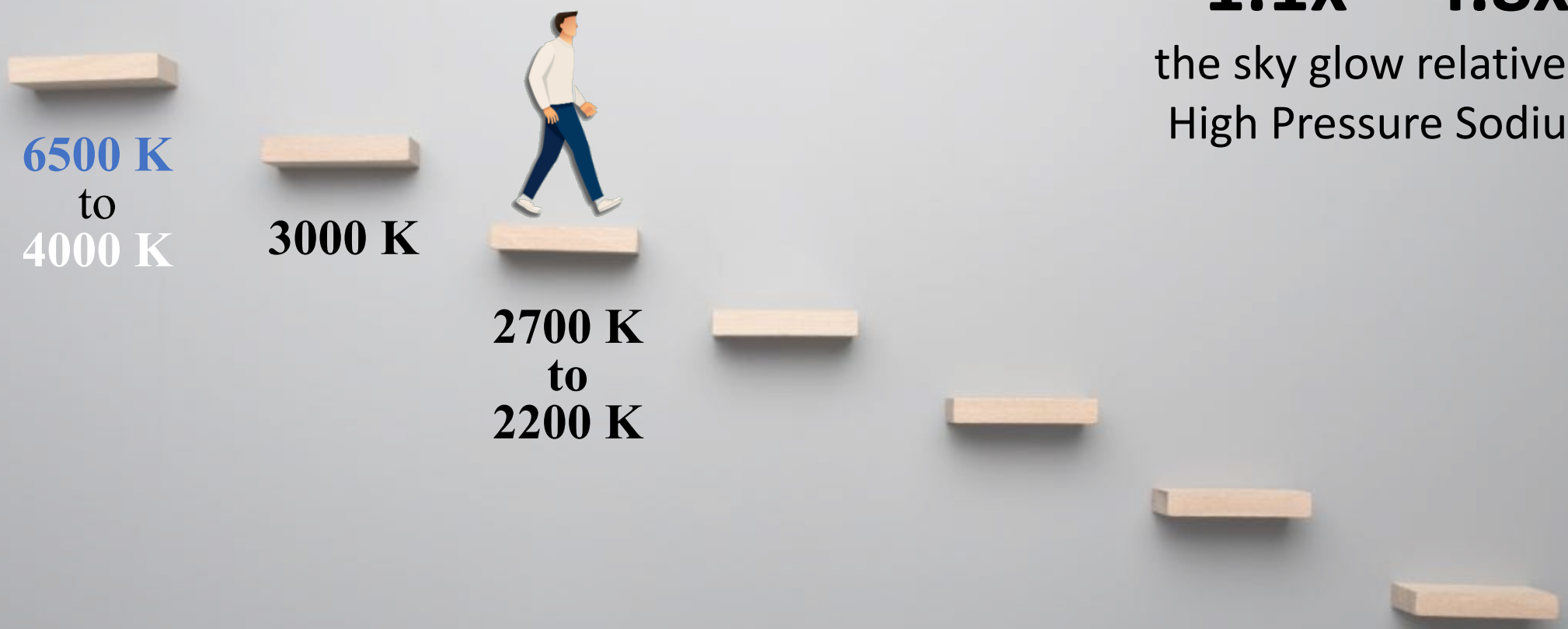
“3000 K”

ANSI C78.377-2017

Less blue light results in less sky glow

1.1x – 4.8x

the sky glow relative to
High Pressure Sodium



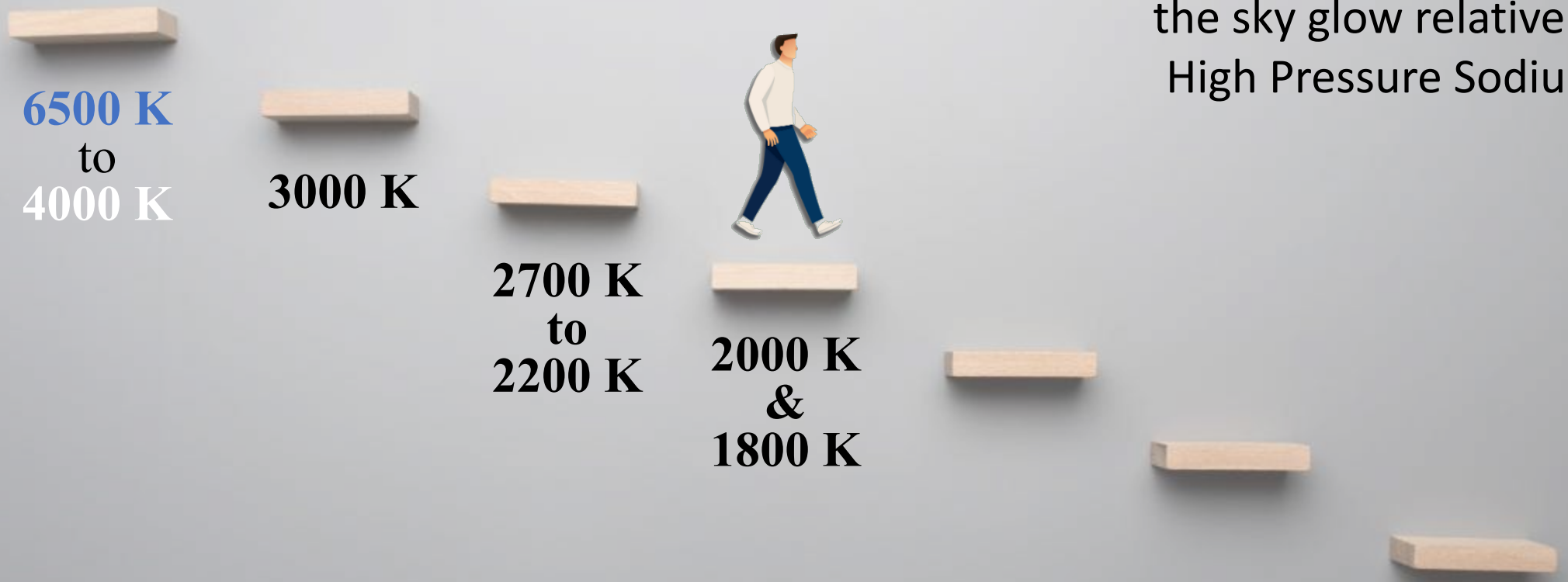
“2700 K” or **“2200 K”**

ANSI C78.377-2017

Less blue light results in less sky glow

0.5x – 4.0x

the sky glow relative to
High Pressure Sodium



“2000 K” or “1800 K”

Esposito and Radetsky [2023]

Less blue light results in less sky glow

0.14x – 1.1x

the sky glow relative to High Pressure Sodium

“PC Amber”

Esposito and Radetsky [2023]

Less blue light results in less sky glow

0.23x – 0.54x

the sky glow relative to High Pressure Sodium

“DE Amber – 590 nm”

Esposito and Radetsky [2023]

Less blue light results in less sky glow

0.1x

the sky glow relative to High Pressure Sodium

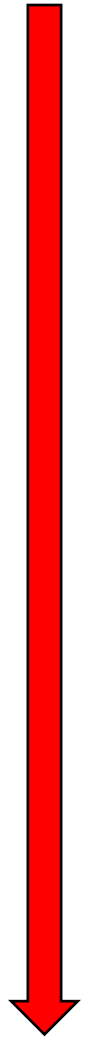
“DE Red – 620 nm”

Esposito and Radetsky [2023]

Specification framework

Table 6. Specification structure for categorizing the chromaticity of light sources relative to the ANSI quadrangles.

Category	Basis	Specification	Impact on Relative Sky Glow (RSG)
Target CCTs from 2200 K to 6500 K	*Basic* or *Extended* Quadrangles from ANSI C78.377–2017	"Categorical CCT" Example: "3500 K," "2200 K," etc.	Higher RSG than high pressure sodium (HPS)
Target CCTs of 2000 K and 1800 K	*Expanded Basic* or *Expanded Extended* Quadrangles from Table 2	"Categorical CCT" Example: "2000 K" or "1800 K"	Many SPDs will have lower RSG than HPS, especially those with less short wavelength emission
PC Amber *(PC Amber implies an SPD with a broadband spectral component generated by a reddish phosphor and may have a noticeable short wavelength "hump")*	Chromaticity tolerance specified in Table 3	When there is no overlap with *Expanded* Quadrangles: "PC Amber" When there is overlap with one of the *Expanded* quadrangles: "PC Amber – 2000 K" Or "PC Amber – 1800 K"	All likely variations of PC Amber will have lower RSG than HPS
DE Amber *(DE Amber LEDs are narrowband with a peak wavelength near approximately 590 nm. They emit light directly – they do not use a phosphor – and have no broadband spectral component.)*	Color Name & Peak Wavelength	"DE Amber – Peak WL nm" Example: "DE Amber – 590 nm"	All variations of DE Amber will have lower RSG than HPS
Other narrowband DE LEDs *(SPDs with chromaticities near the spectrum locus and peak wavelengths longer than approximately 595 nm)*	Color Name & Peak Wavelength	"DE Color Name – Peak WL nm" Example: "DE Red – 640 nm"	Lowest RSG; lower RSG than DE Amber



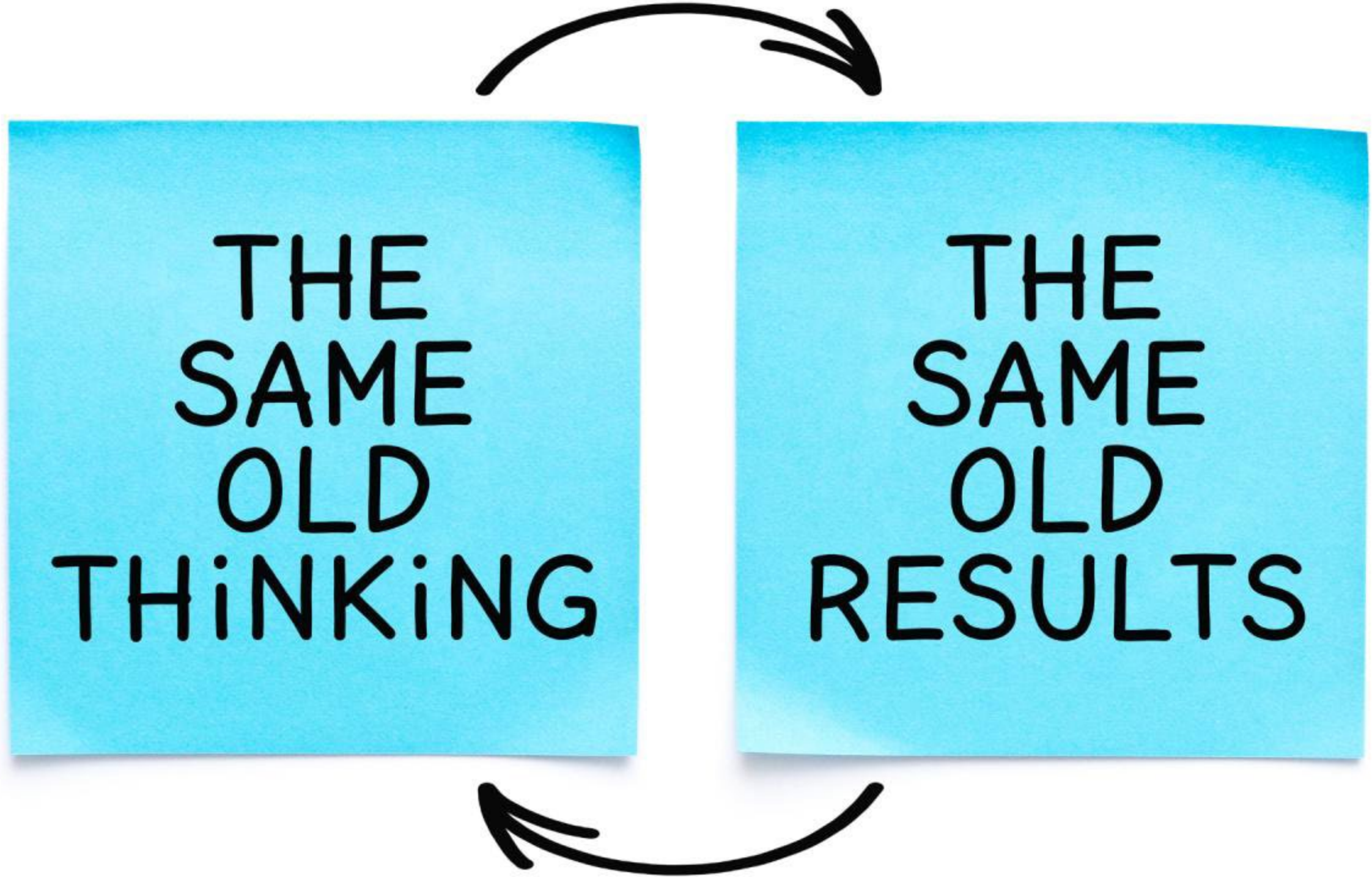
Decreasing Sky Glow

(on average)

Esposito T, Radetsky L. 2023. Specifying non-white light sources in outdoor applications to reduce light pollution. LEUKOS.

Side bar:
We can just use CCT to predict sky glow, right?

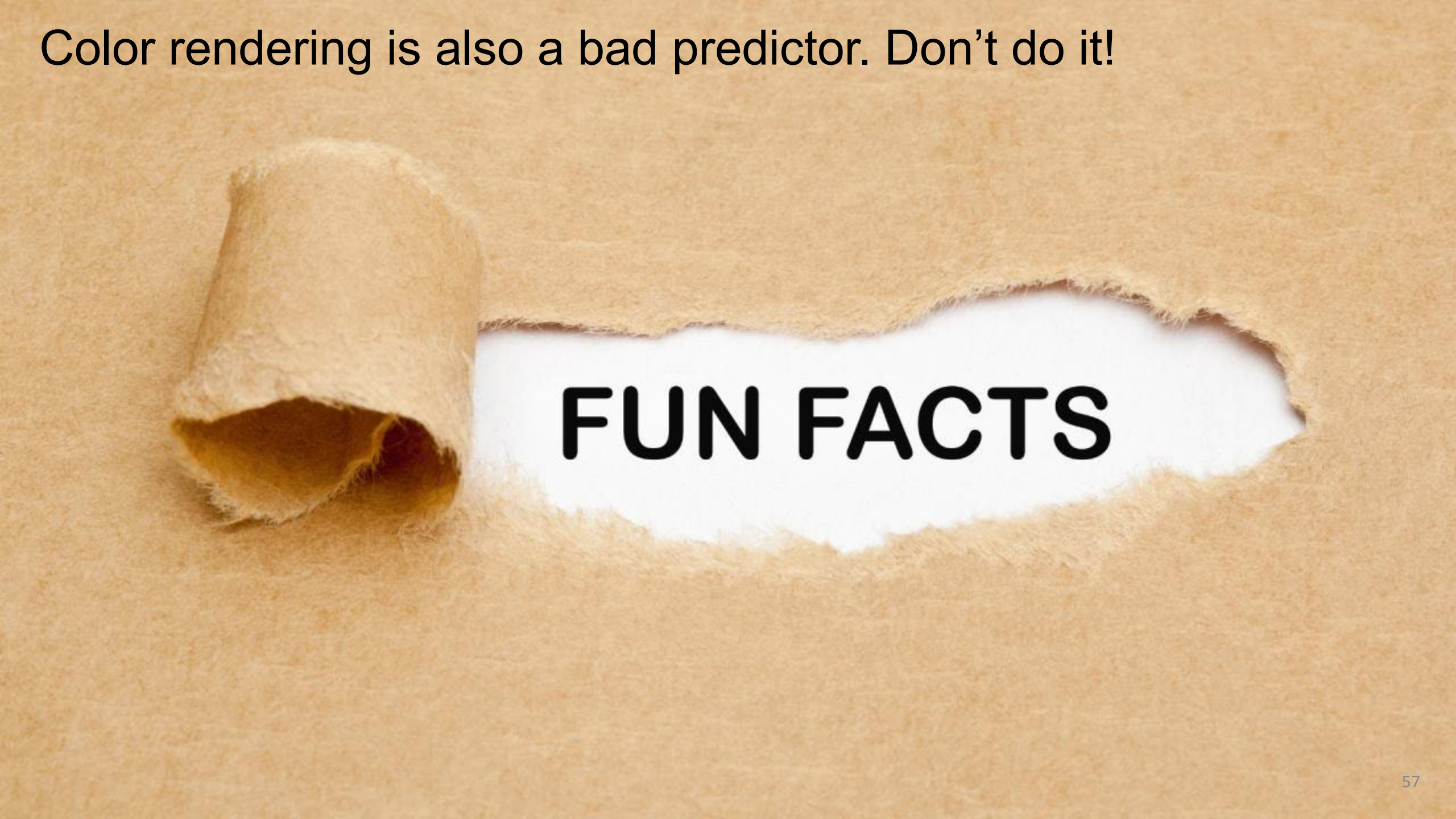

RIGHT
WRONG


THE
SAME
OLD
THiNKiNG
THE
SAME
OLD
RESULTS

CCT is a mediocre predictor of RSG

S/P ratio is the best predictor of RSG

Color rendering is also a bad predictor. Don’t do it!



Solution 3:

New Specification Tools

https://ideogram.ai/

Multiple tools will be needed

Photo by Karla Hernandez on Unsplash

PNNL Sky Glow Comparison Tool

Sky Glow Comparison Tool

INPUT CONDITIONS

1. Scenario Parameters

Observer location	near
Atmospheric condition	clear low particulate
Weighting function	scotopic

2. Baseline Light Source Characteristics

Percent uplight	0%
Baseline source	1. HPS Example

3. Comparison Light Source(s) Characteristic

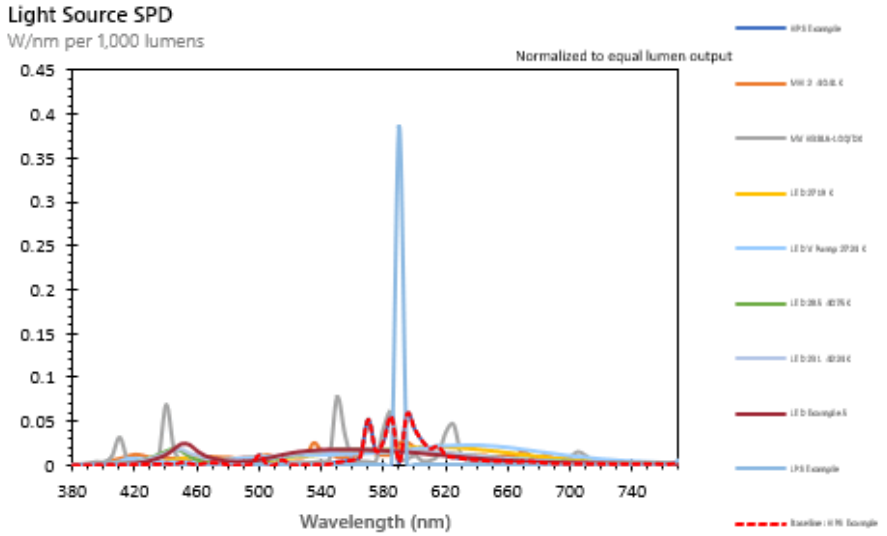
Percent uplight	0%
Lumen output (% of baseline)	100%

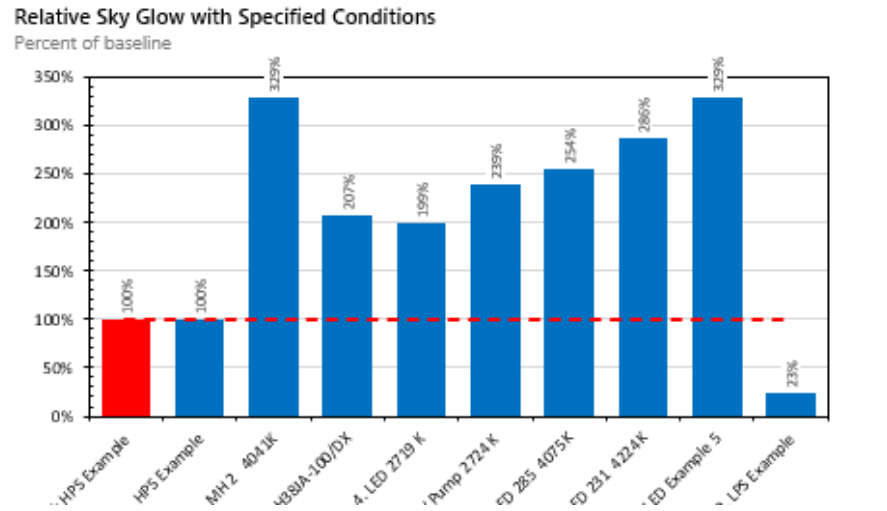
Clear | Calculate

RESULTS

[Add new SPDs using the "SPD Input" sheet]

Source Label	Glow
BASELINE: HPS Example	1.00
1. HPS Example	1.00
2. MH 2 4041K	3.29
3. MV H38JA-100/DX	2.07
4. LED 2719 K	1.99
5. LED V Pump 2724 K	2.39
6. LED 285 4075K	2.54
7. LED 231 4224K	2.86
8. LED Example 5	3.29
9. LPS Example	0.23





Get it from: DOE.SSL.UPDATES@ee.doe.gov

Supplemental Calculator in LEUKOS paper

This sheet can be used to determine non-white light specifications

[Reference: Esposito T, Radetsky L. 2023. Specifying non-white light sources in outdoor applications to reduce light pollution. https://doi.org/10.1080/15502724.2022.2121285.]

Instructions

STEP 1 Load a TEST spectral power distribution (SPD) using the IES TM-30 interface on the 'Calculator' tab. Refer to the 'Instructions' tab for assistance. Return to this tab after SPD has been loaded.

Note: SPDs have been added to the 'SPD Library' tab for PC Amber, Amber, Red, Far Red, and PC 2000 K and PC 1800 K LEDs. SPDs for high-pressure and low-pressure sodium have also been added. These SPDs have SPD #'s from 350 to 362.

STEP 2 Choose the lighting technology for the TEST SPD from the drop-down menu in cell C11. There are three choices:

(1) **Phosphor-Converted (PC) Amber LEDs:** these have a peak wavelength near 590 nm, a wide distribution, and a small or no hump between 400 nm and 500 nm. See **Figure 2** for example SPDs when this technology is selected.

(2) **Direct-Emission (DE) LEDs:** these have a very narrow distribution, typically less than a width of 25 nm at their half-maximum value. See **Figure 2** for example SPDs when this technology is selected.

(3) **Other:** this includes other SPDs such as those from phosphor-converted white LEDs, high pressure sodium, etc. See **Figure 2** for example SPDs when this technology is selected.

STEP 3 If the technology type is properly selected and no error message is displayed, the lighting specification will be provided in cell C15.

Note: a nominal color name is automatically added to Direct-Emission (DE) LEDs. These color names are notably subjective and may vary from person to person. The limits for the color names can be modified in cells N30:O35 of the 'RefNWL' tab.

Step 2 (manual): Choose your lighting technology below ↓↓↓↓↓

Technology dropdown menu: Phosphor-Converted (PC) Amber LED

Technology description: Phosphor-converted (PC) Amber LEDs sometimes have a blue hump (near 450 nm) and always have a large hump near 590 nm.

Step 3 (automatic): **Specification**

Specification: PC Amber – 1800 K

Error Message: None

Version Notes | Instructions | Calculator | NWL Specification | RefNWL | Results Graphical | Results Numerical | CVG | Simple Report | Intermediate Report

Figure 1. Test and reference SPDs.

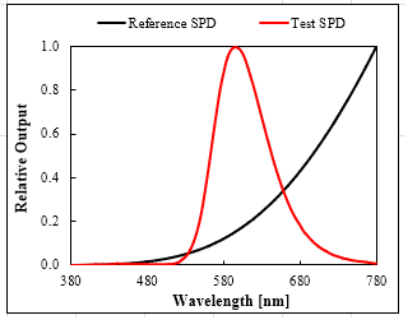


Figure 2. Example SPDs for selected lighting techno

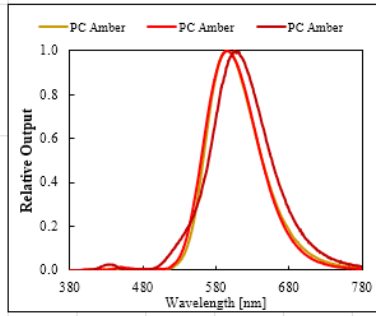
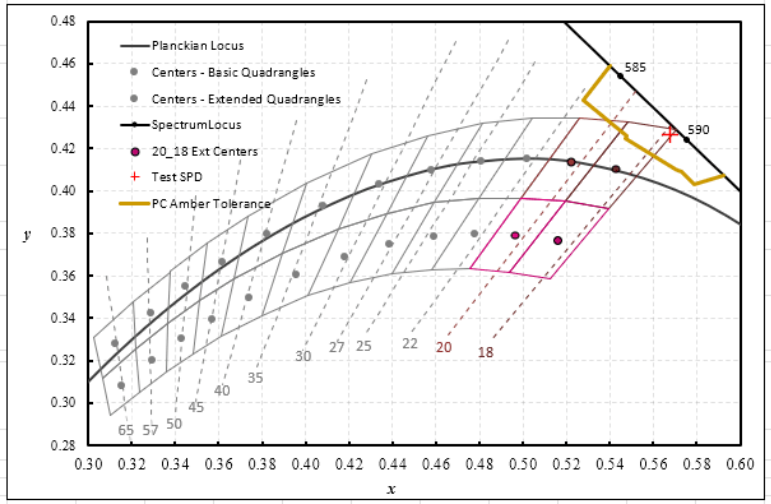


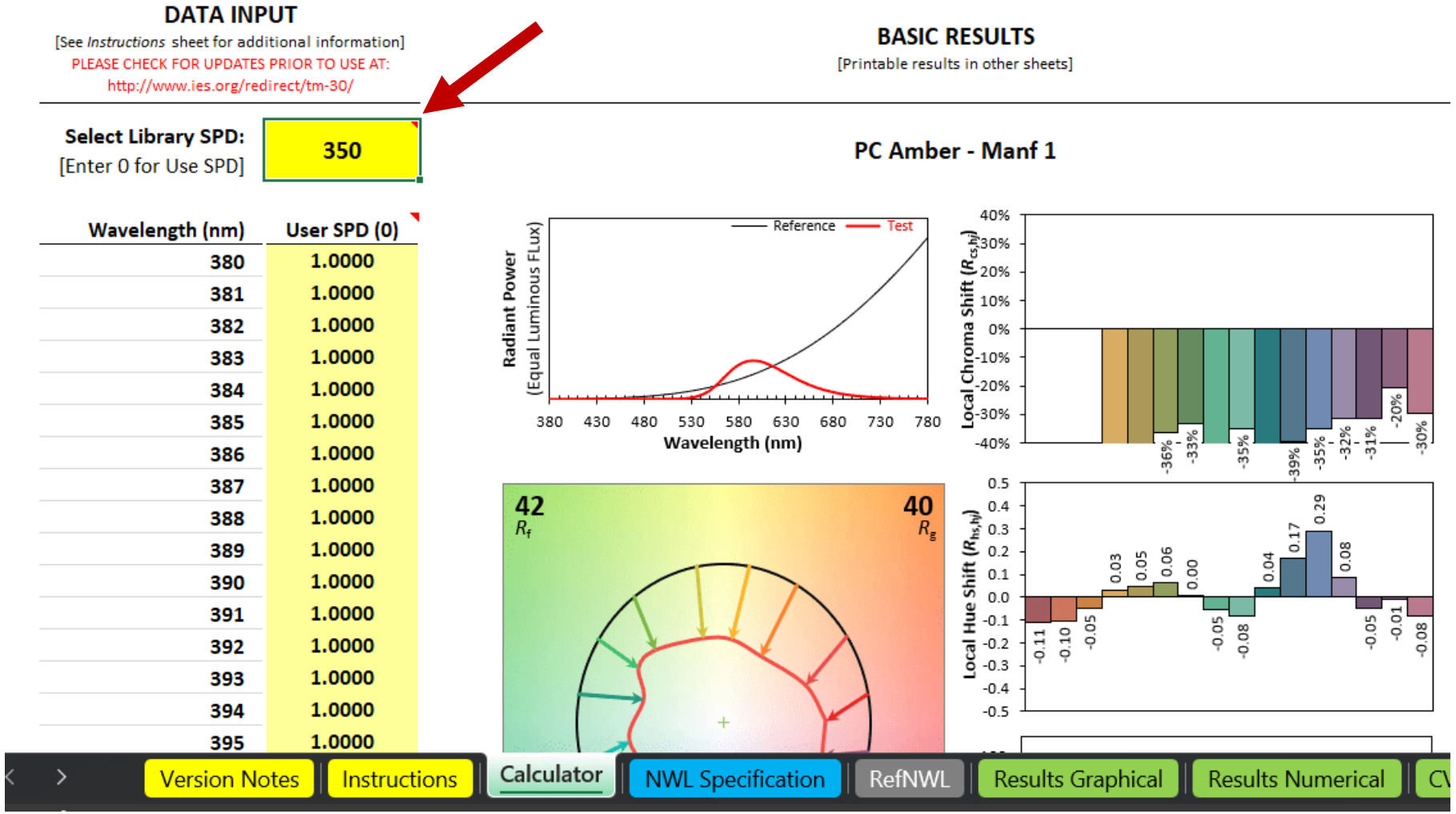
Figure 3. An enlarged portion of the CIE 1931 *xy* chromaticity diagram showing the ANSI C78.377-2017 7-step *Basic* and *Extended* CCT Quadrangles, the proposed *Expanded Basic* and *Expanded Extended* quadrangles for nominal CCT designations of 2000 K and 1800 K from Esposito and Radetsky [2023], and the proposed PC Amber bin (yellow) from Esposito and Radetsky [2023].



Download free Excel Tool:

https://ndownloader.figstatic.com/files/38896930

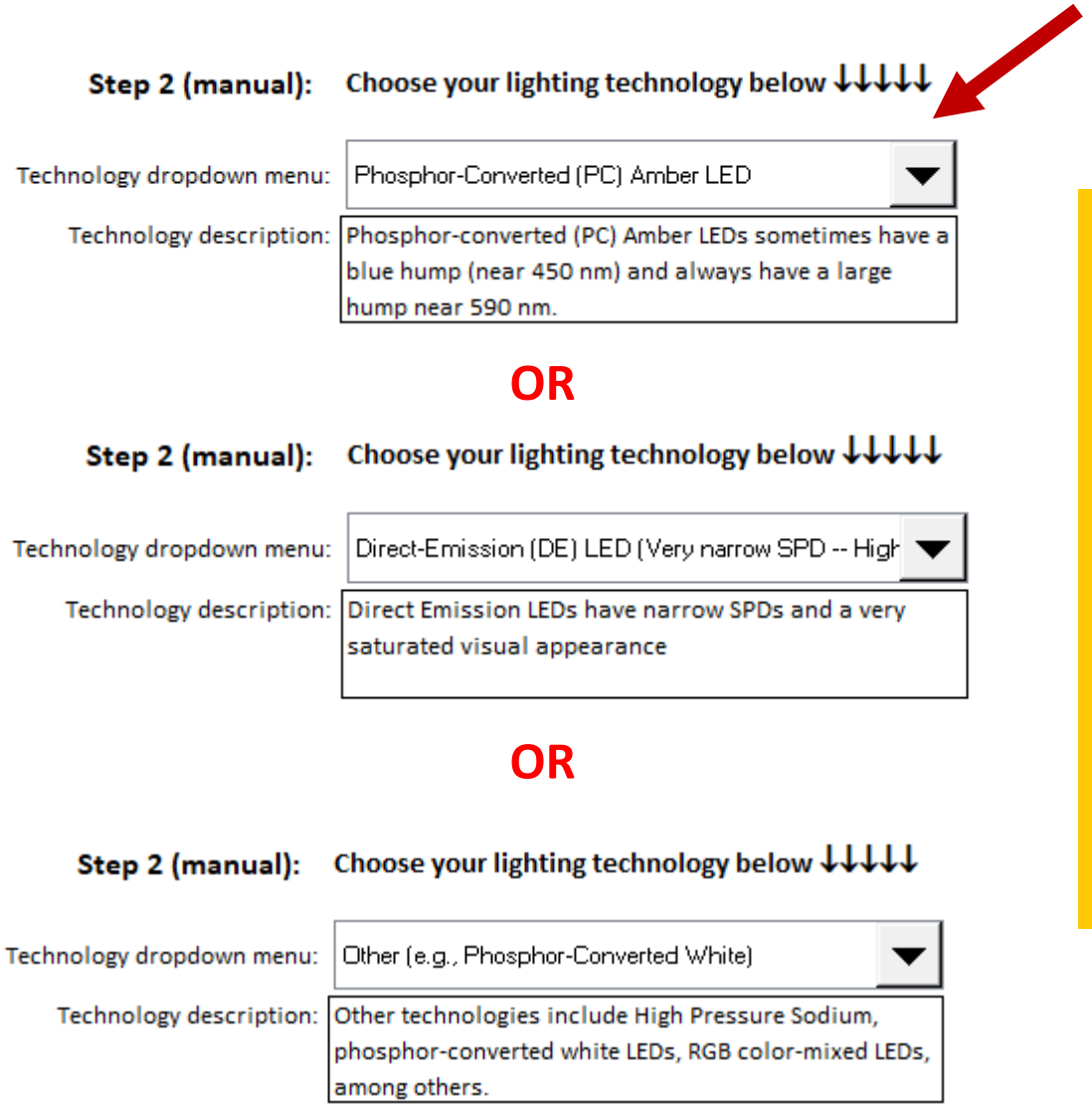
Supplemental Calculator in LEUKOS paper



Step 1:

- From the "Calculator" tab, select or enter SPD data

Supplemental Calculator in LEUKOS paper



Step 2:

- In the "NWL Specification" tab, choose the technology type from the Step 2 dropdown menu
- The Test SPD and Example SPDs are shown at the top to provide guidance.
- Hint: An error will be shown in Step 3 if you select incorrectly

Supplemental Calculator in LEUKOS paper

Step 2 (manual): **Choose your lighting technology below ↓↓↓↓↓**

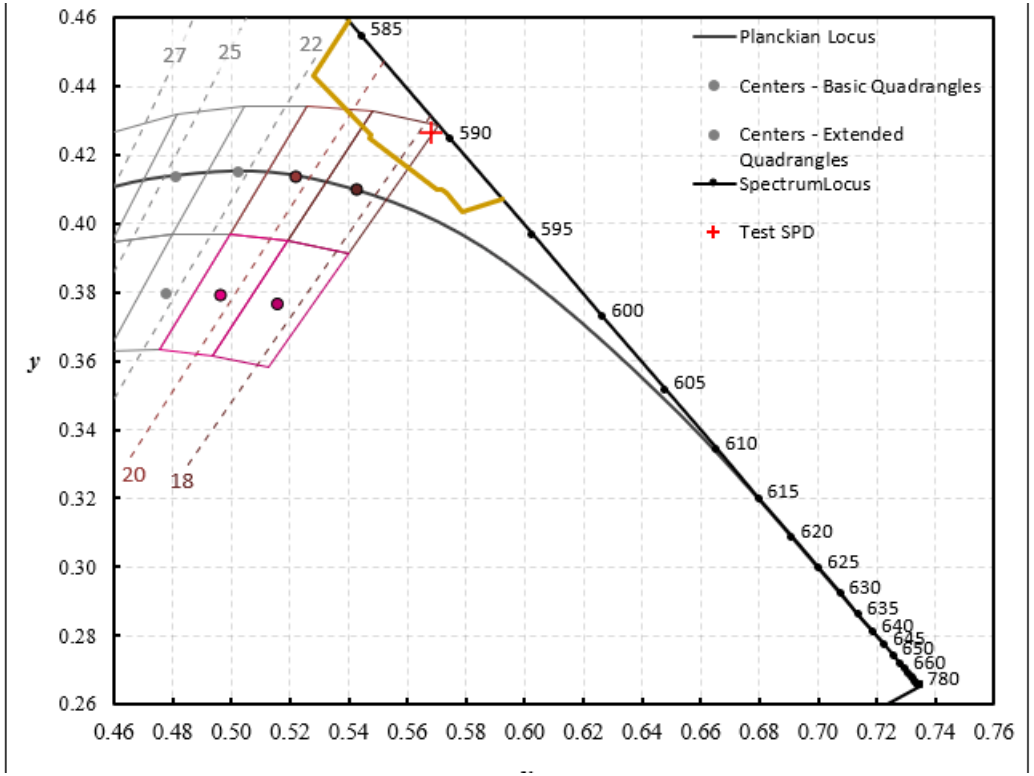
Technology dropdown menu: Phosphor-Converted (PC) Amber LED

Technology description: Phosphor-converted (PC) Amber LEDs sometimes have a blue hump (near 450 nm) and always have a large hump near 590 nm.

Step 3 (automatic): **Specification**

Specification: PC Amber – 1800 K

Error Message: None



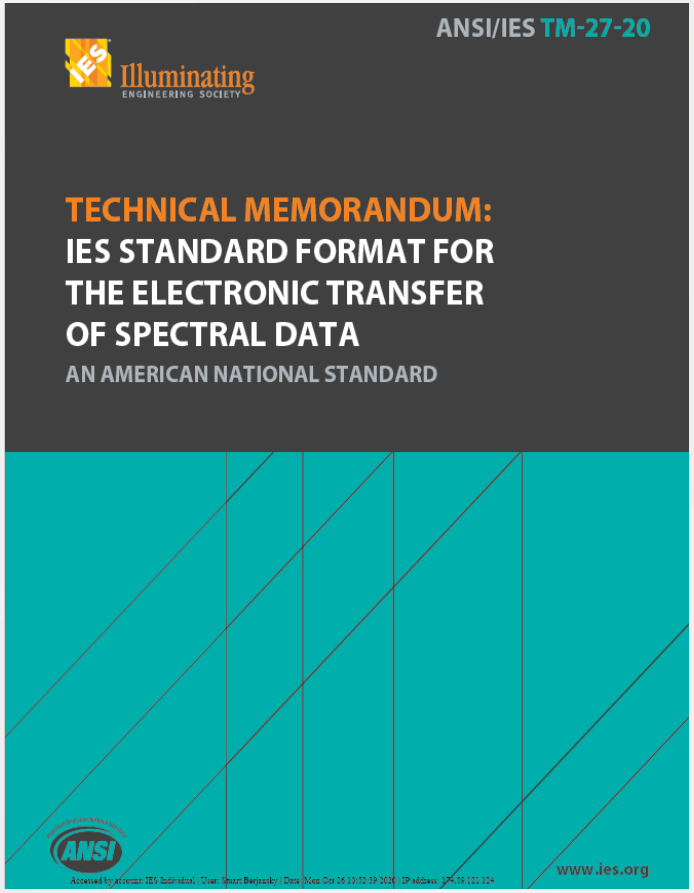
Step 3:

- The Specification box will show the specification, or an error, depending on the manual selection made in Step 2.
- The SPD's chromaticity coordinates are shown in the figures on the left

The future we deserve:

spectral data files and conforming software

We need to use better inputs to get better outputs (starting with SPDX files)



It's not easy to get these files


DLC's SSL/LUNA QPL
Ask manufacturers
IES TM-30 Calculator – Example Library

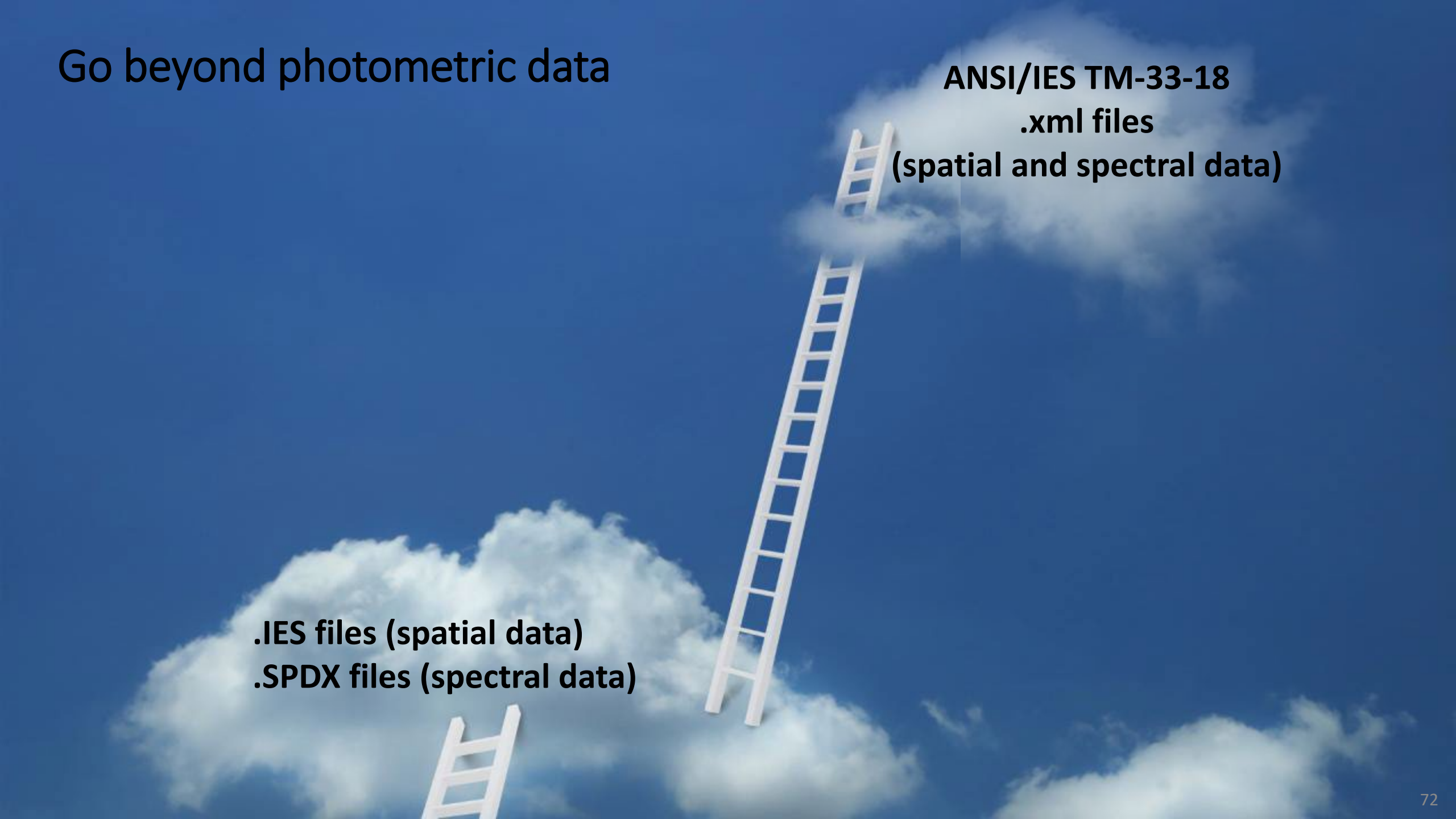
Using .SPDX files?

Many future use cases

Light pollution assessment
Glare assessment
Non-visual biological responses
Horticultural lighting
Agricultural lighting

Photo by Alexander Hafemann on Unsplash

Go beyond photometric data



Looking forward

CALL TO ACTION

CHROMATICITY

NOMENCLATURE

COLOUR

CALCULATIONS

Progress is happening

References

- Sánchez de Miguel, Alejandro, Jonathan Bennie, Emma Rosenfeld, Simon Dzurjak, and Kevin J. Gaston. 2021. "First Estimation of Global Trends in Nocturnal Power Emissions Reveals Acceleration of Light Pollution" *Remote Sensing* 13, no. 16: 3311. https://doi.org/10.3390/rs13163311
- Kyba, Christopher C. M., Yiğit Öner Altıntaş, Constance E. Walker, and Mark Newhouse. 2023. "Citizen Scientists Report Global Rapid Reductions in the Visibility of Stars from 2011 to 2022." *Science* 379 (6629): 265–68. https://doi.org/10.1126/science.abq7781.
- Avalon C.S. Owens, Précillia Cochard, Joanna Durrant, Bridgette Farnworth, Elizabeth K. Perkin, Brett Seymoure, Light pollution is a driver of insect declines, Biological Conservation, Volume 241, 2020, 108259, ISSN 0006-3207, https://doi.org/10.1016/j.biocon.2019.108259.
- Francisco Sánchez-Bayo, Kris A.G. Wyckhuys, Worldwide decline of the entomofauna: A review of its drivers, Biological Conservation, Volume 232, 2019, Pages 8-27, ISSN 0006-3207, https://doi.org/10.1016/j.biocon.2019.01.020.
- Burt, Carolyn S., Jeffrey F. Kelly, Grace E. Trankina, Carol L. Silva, Ali Khalighifar, Hank C. Jenkins-Smith, Andrew S. Fox, Kurt M. Fristrup, and Kyle G. Horton. 2023. "The Effects of Light Pollution on Migratory Animal Behavior." *Trends in Ecology & Evolution* 38 (4): 355–68. https://doi.org/10.1016/j.tree.2022.12.006.
- La Sorte, Frank A., Kyle G. Horton, Alison Johnston, Daniel Fink, and Tom Auer. 2022. "Seasonal Associations with Light Pollution Trends for Nocturnally Migrating Bird Populations." *Ecosphere* 13 (3). https://doi.org/10.1002/ecs2.3994.
- Falcón, Jack, Alicia Torriglia, Dina Attia, Françoise Viénot, Claude Gronfier, Francine Behar-Cohen, Christophe Martinsons, and David Hicks. 2020. "Exposure to Artificial Light at Night and the Consequences for Flora, Fauna, and Ecosystems." *Frontiers in Neuroscience* 14 (November): 602796. https://doi.org/10.3389/fnins.2020.602796.
- Kernbach, Meredith E, Vincent M Cassone, Thomas R Unnasch, and Lynn B Martin. 2020. "Broad-Spectrum Light Pollution Suppresses Melatonin and Increases West Nile Virus–Induced Mortality in House Sparrows (Passer Domesticus)." *The Condor* 122 (3): duaa018. https://doi.org/10.1093/condor/duaa018.
- Esposito, Tony, and Leora C. Radetsky. 2023. "Specifying Non-White Light Sources in Outdoor Applications to Reduce Light Pollution." *LEUKOS* 19 (3): 269–93. https://doi.org/10.1080/15502724.2022.2121285.
- Kinzey, Bruce R., Tess E. Perrin, Naomi J. Miller, Miroslav Kocifaj, Martin Aube, and Hector A. Lamphar. 2017. "An Investigation of LED Street Lighting's Impact on Sky Glow." PNNL--26411, 1418092. https://doi.org/10.2172/1418092.
- https://www.designlights.org/news-events/news/light-at-night-and-the-inequality-gap-update-progress-and-challenges/
- ANSI Standards Action Nov 10, 2023 PINS announcement https://share.ansi.org/Shared%20Documents/Standards%20Action/2023-PDFs/SAV5445.pdf

Thank you!

Questions?

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