Color & Light

A lighting design guide to color temperature, tuning and rendering

To overcome the lack of natural light in a given space—or to maximize the value of natural lighting on human biology—improved lighting now permits and necessitates integration with nature. Human-centric commercial lighting can expedite patient recovery in hospitals, improve productivity in conferences and office spaces and sharpen and enhance learning in the classroom.

ACON LIGHTING

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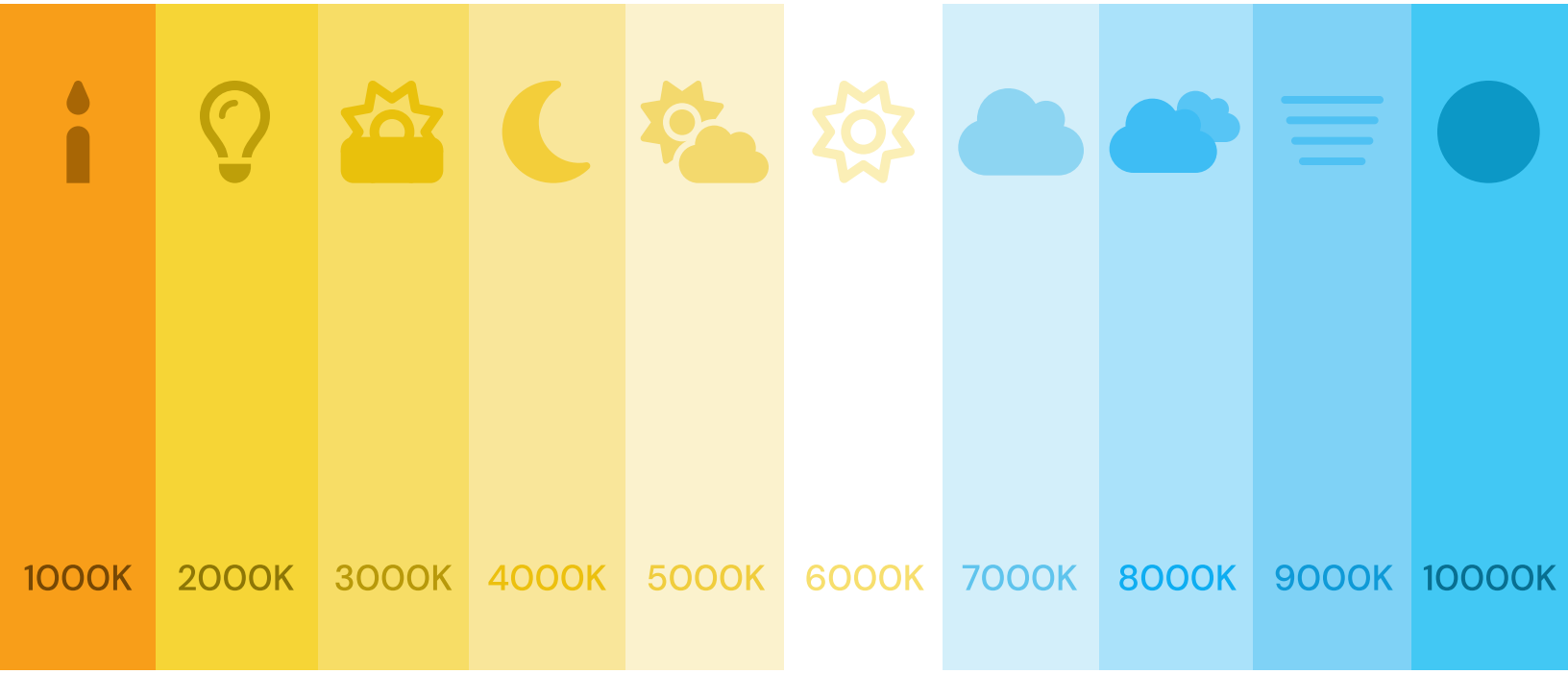
Understanding color temperature

Correlated Color Temperature (CCT) is a gauge of how yellow or blue light emitted at a particular Kelvin temperature appears. CCT focuses on the visible spectrum of white light and how it appears on the warm-to-cool scale relative to Kelvin. In short, the more energy and heat applied to an object, the cooler the object appears.

WARM LIGHT DAYLIGHT **COLD** LIGHT



Today, this scale represents the range of colors in interior lighting, especially as it mimics natural sources.

Daylight

- Generally very cool
- Color temperature: 5300K-5500K

Sunrise and sunset

- Warmer
- Color temperature: 2000K-3000K

Artificial light has as much variation in **CCT** as natural sources:

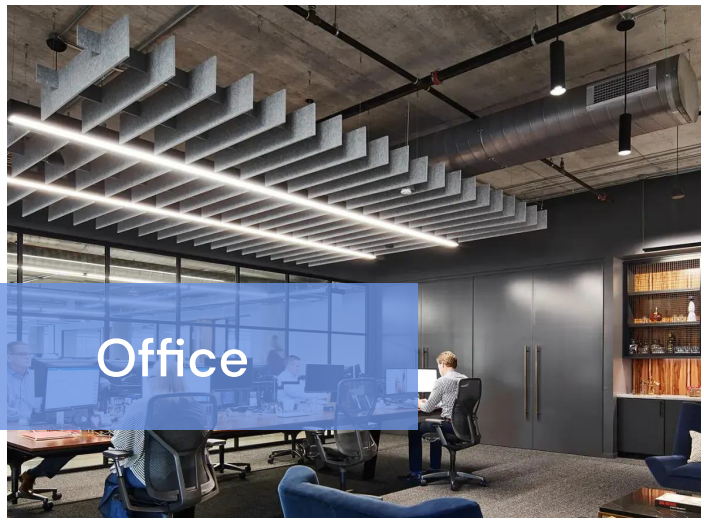
Light Source	Typical Color Temperature Range	Capable Color Temperature Range
Candelight	1850K-1930K	1000K-2000K
Household Tungsten and Standard Incandescent Lights	2500K-2900K	2200K-3500K
Halogen Light Sources For Theatrical Applications	3000K	2330K-3200K
Compact Fluorescent Bulb	4200K	2700K-5000K
LED Lights	2700K-5000K	1800K-6000K

Color temperature in lighting design

The color of light plays a role in how one perceives an environment.

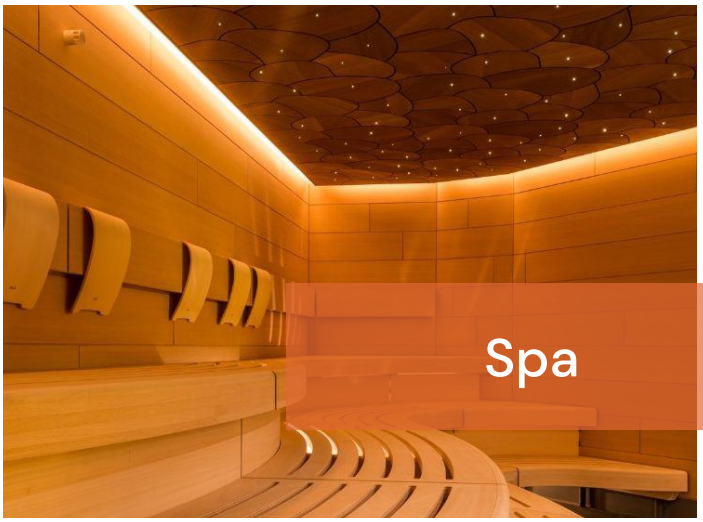
For this reason, choosing color temperature can be one of the most crucial factors in lighting a space.

Consider two commercial environments:



Office

- Filled with bright, invigorating light
- Motivates workers to be productive

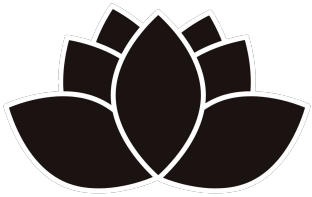


Spa

- Warm, soothing light
- Encourages patrons to unwind and destress

The mind is most active when the sun is brightest. As the sun reaches the horizon, the body begins to relax. Light signals the brain to control hunger response, body temperature and hormonal secretion.

Recent studies show health improves in environments where artificial lighting mimics the sun's color temperature throughout the day.



RELAXATION

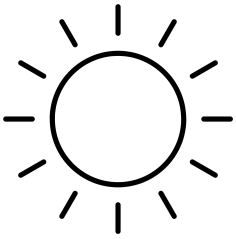
2000K—3000K

For relaxation, place lamps that are closer to golden hour sunlight or candlelight.

FOCUS

3500K—4100K

When sharp focus is needed, select a color temperature that is closer to daylight.



MULTIPURPOSE

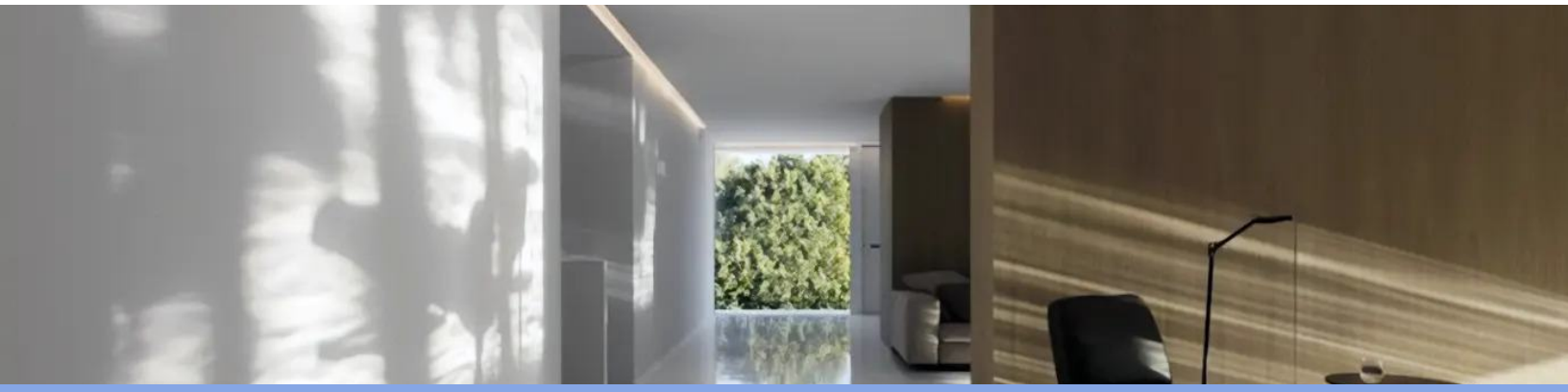
3500K—5000K

In areas that fluctuate purposes, mimic the angle of the sun for the color temperature.

Warmer light tends to be relaxing because one's internal clock associates the light with ending the day and preparing to sleep.

Cooler colors have the opposite effect because that clock tells us it is the middle of the day when we should be busy.

Color temperature and fixture height



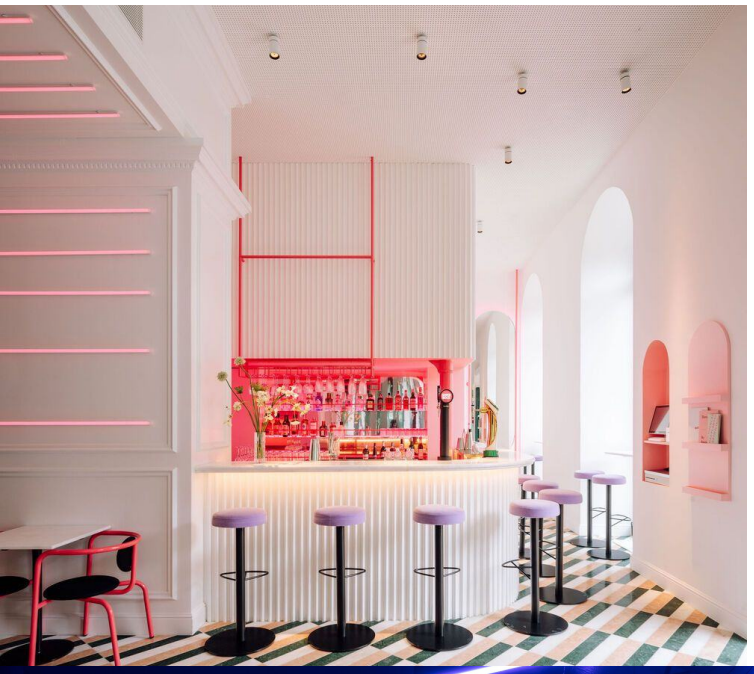
Daylight at the beginning and end of the day is somewhat warm, and many believe that the interior should respond in a similar manner. As the height of the fixture approaches the floor, the color temperature warms up, mimicking the natural cycle of the sun. In rooms where daylight provides ambient lighting, designers should select a commensurate color temperature.

As established, daylight is on the cooler end of the spectrum. Lamps in the 5500k and over range appear to be too cold after the sun has set. For this reason, some designers choose to place lamps in the 3500K and 4100K range. This neutral range isn't too warm when combined with daylight and doesn't appear blue in the evening. 3000K will be noticeably warmer and may suit when a warm color temperature is desired at night.

Color temperature in commercial applications

Lights at a certain Kelvin color temperature suit specific commercial interiors and help create an atmosphere.

What is color tuning?

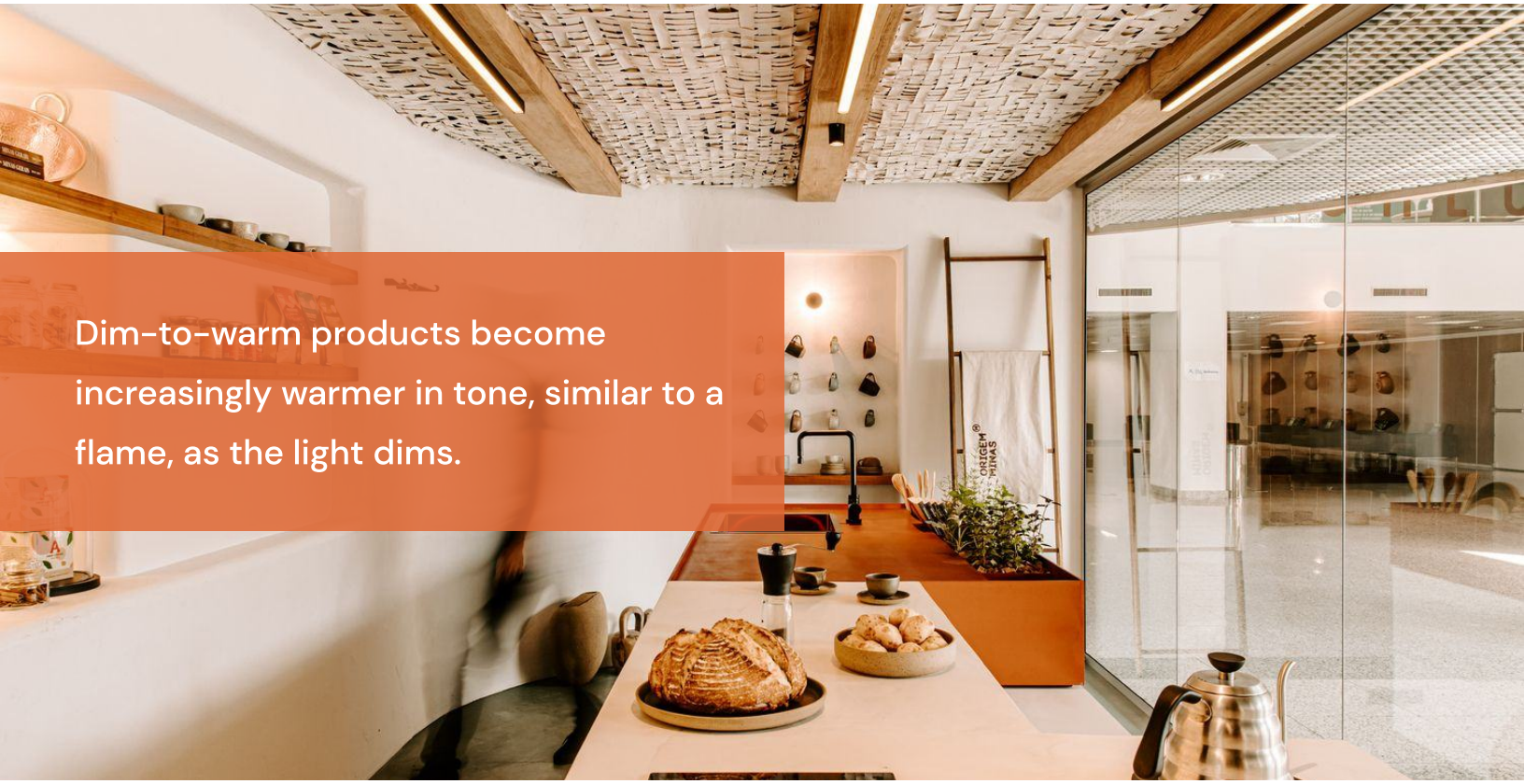


Today's LED color tuning systems allow users to control the color of light anytime after installation. Color-tunable light fixtures can harvest daylight and control color temperature throughout the day, changing from daylight to cool white to warm white as the day progresses.

Color tuning also affords the ability to attune lighting to individual preferences or specific application needs.

For example, the user can set the LED light fixture to follow the sun's natural east-to-west course throughout the day or choose from standard presets (i.e., dawn, morning, midday, afternoon and evening). Three types of color-tunable technologies allow users to tune lighting fixtures in a residence or workplace.

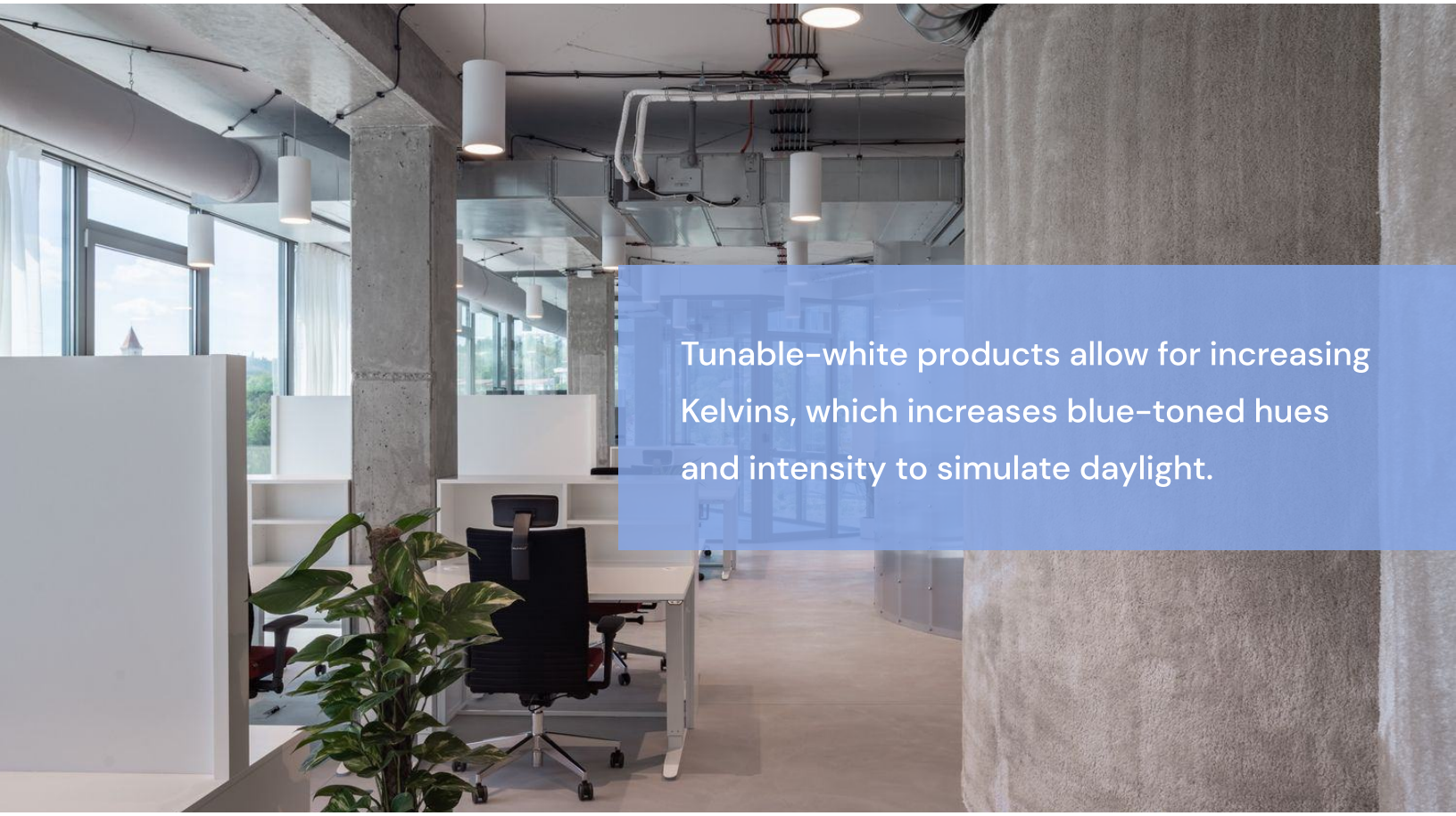
Color-tunable technologies:
Dim-to-warm



Dim-to-warm products become increasingly warmer in tone, similar to a flame, as the light dims.

- 1800K–2700K range
- Mimics incandescent lighting or candlelight
- Works best in:
  - Restaurants
  - Lobbies
  - Hotel guest rooms
  - Ballrooms
  - Theaters
  - Homes

Color-tunable technologies:
Tunable-white



- 2700K-5000K range
- Mimics daylight
- Works best in:
  - Medical facilities
  - Offices
  - Museums
  - Art studios

Color-tunable technologies: Full-color-tuning

Full-color tuning products, also known as RGB, RGBA, RGBW or color changing, use primary colors to produce most colors across the color spectrum.

RGBW (Red, Green, Blue, White), RGB (Red, Green, Blue), or RGBA (Red, Green, Blue, Amber)

Provides a full range of color wheel and tunable-white. Some options are not tunable and come with a dedicated white in either:

- Warm white (around 2700K)
- Neutral white (around 3500K)
- Cool white (around 4100K)
- Daylight white (around 6000K)

Works best in:

- Theatrical/entertainment/exhibition applications
- Playful residential programs
- Commercial cove lighting applications
- Direct-view fixture applications
- Children's programs such as schools/ Healthcare
- Gyms or performance programs

The difference between CCT and CRI

Correlated Color Temperature (CCT) is not to be confused with Color Rendering Index (CRI). While color temperature varies throughout the day, CRI does not change.

Color rendering is the ability of a light source to accurately reveal the color of an object. The traditional measure of color rendering is the Color Rendering Index (CRI).

Sunlight shows the true colors of an object and, therefore, has a perfect CRI of 100. It's the natural light standard against which all other light sources are compared when calculating CRI.

The color of clothing in the store, food on the kitchen counter and even skin appear different depending on the light that's illuminating the object.

CRI in lighting design

A CRI of 90 means that the artificial light source is replicating roughly 90 percent of the visible color spectrum that the sun would produce on the same color.

Certain applications that may require 90+ CRI lighting:

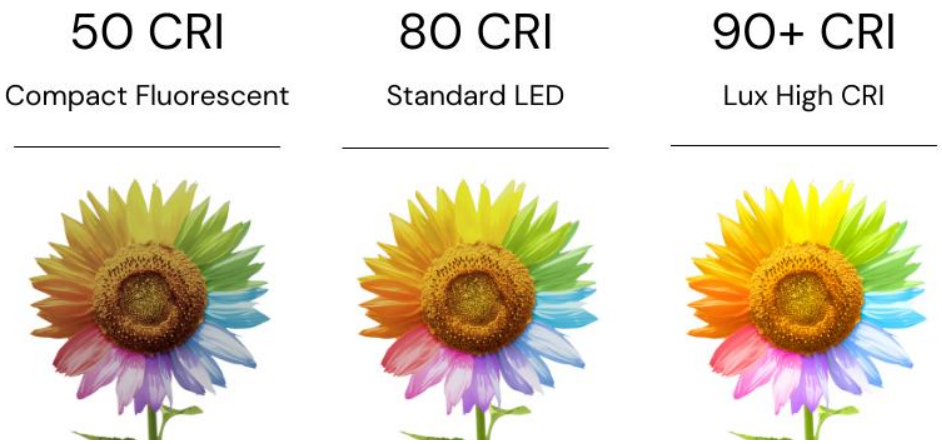
Commercial

- Art galleries
- Museums
- Dining
- Retail outlets
- Medical facilities
- Offices

Residential

- Areas where people apply makeup
- Areas for work where color is important, such as design and construction

Color Rendering Index (CRI)



How is CRI measured?

Formal CRI measurement is conducted in a laboratory, often as part of the larger process of testing and certifying a product.

The light source being tested is directed onto a set of reference colors, and its color rendering performance is measured by a spectrophotometer—an instrument that measures the number of photons (intensity of light) absorbed after passing through the sample solution.

Each resulting color is then compared with the benchmark (reference colors as measured in sunlight). Then the values are averaged to provide an overall CRI rating.

The limitations of CRI

The traditional CRI metric is based on a set of eight reference colors. However, red tones are not well-represented. Accordingly, a light source with a high CRI rating may still render reds poorly.

And because a CRI rating averages eight colors, there may be slight performance variation across the spectrum, even in products with a high CRI rating.

In recent years, an extended CRI has been used with 15 reference colors.

Light sources and CRI

Incandescent and halogen light sources both have high (90+) CRI ratings. The light from fluorescent and other discharge lamps is composed of a limited range of wavelengths; therefore, these light sources do not merit a high CRI rating.

With the emergence of new lighting technologies, such as LEDs, demand for a more comprehensive and accurate color rendering evaluation method arose.

This led to the development of ANSI/IES TM-30-20, a revolutionary approach to assessing color rendition in lighting.

The rise of TM-30-15: A more comprehensive approach

To address the limitations of CRI and provide a fuller evaluation of color rendering, the Illuminating Engineering Society (IES) introduced TM-30-15 in 2015. This new method offers a more extensive palette of 99 colors. Additionally, TM-30 measures color fidelity, gamut and color vector graphics.

These R-value properties are desired based on the architectural application. High R9 values are commonly specified for residential or hospitality applications, where rendering skin color creates a vibrant human-centric experience.

3 Color Rendering Scales

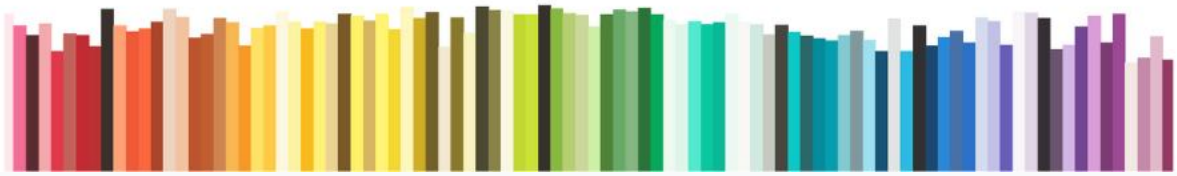
Standard CRI Rating (R1-R8)

R1	R2	R3	R4	R5	R6	R7	R8
Light Greyish Red	Dark Greyish Yellow	Strong Yellowish Green	Moderate Yellowish Green	Light Blue	Blueish Green	Violet	Reddish Purple

Extended CRI Rating (R1-R15)

R9	10	R11	R12	R13	R14	R15
Saturated Red	Saturated Yellow	Saturated Green	Saturated Blue	Skin Color (Light)	Olive Green	Skin Color (Medium)

TM-30-15



Color Fidelity Index (Rf)

- Measures the average color rendering performance of a light source across 99 different colors
- A higher Rf score indicates better color accuracy
- A perfect score of 100 represents a light source that renders colors identically to the reference source

Gamut Index (Rg)

- Measures the saturation of colors rendered by a light source compared to a reference source, providing valuable information about the intensity and vibrancy of colors
- A higher Rg score indicates higher color saturation
- A lower score suggests under-saturation

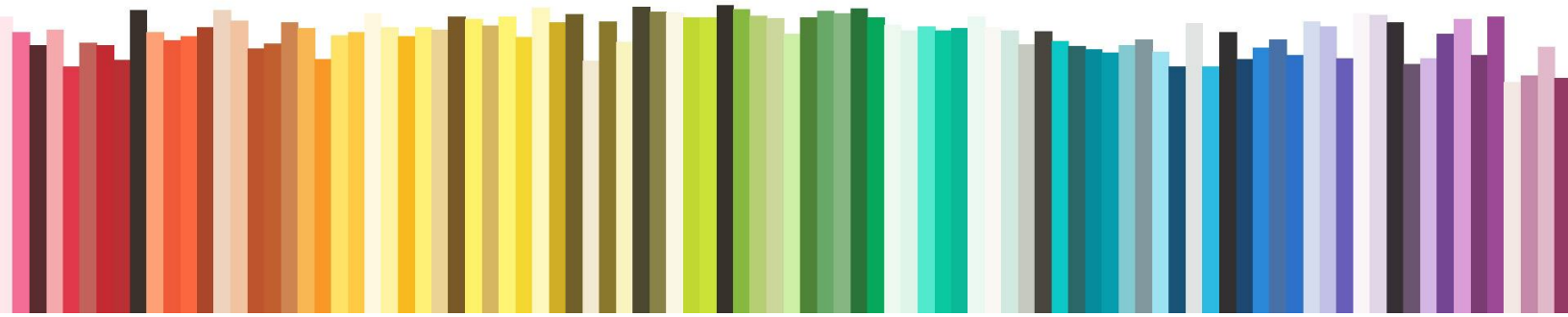
Color Vector Graphics

- Offers a visual representation of color saturation anomalies
- A circular vector graph overlays a color space, indicating where the light source may deviate from the reference source in terms of color saturation
- By visualizing the specific color areas affected by saturation discrepancies, designers can make more informed decisions about the use of light sources in different applications

The advancements of TM-30-20: A further refinement

Building upon the foundation of TM-30-15, the IES introduced an updated version, TM-30-20.

TM-30-20 offers enhancements and refinements to the evaluation method for more comprehensive and accurate assessment of color rendering.



It uses a wider palette of 99 reference colors, chosen from real-world objects, to evaluate the color fidelity and saturation of a light source. It offers improved calculations and better alignment with subjective visual outcomes.

TM-30-20 takes into consideration the entire spectrum of light emitted by LEDs, making it a suitable method for evaluating the color rendering capabilities of modern sources.

Specifying color rendering requirements

TM-30-20 offers a comprehensive set of recommended specification criteria that can be applied in various lighting design scenarios. The specification criteria are based on **three design intents:**

01 Preference

- Focuses on subjective evaluations of pleasantness, naturalness and acceptability of color rendering
- Relevant in retail, office, hospitality and residential lighting applications

02 Vividness

- Focuses on subjective evaluations of color vividness, saturation and vibrancy
- Relevant in entertainment, display and retail applications

03: Fidelity

- Focuses on achieving a high match between a test light source and its reference
- Relevant in applications like healthcare and color matching, where color accuracy is of utmost importance

Understanding priority levels

Each design intent has three priority levels, allowing specifiers to fine-tune their requirements based on the specific needs of a project.

- **Priority Level 1** has the strictest requirements, ensuring the highest level of color accuracy or saturation. However, it may limit the available selection of light sources
- **Priority Level 3**, on the other hand, allows for variability in color rendering performance but still meets the general intent

Evaluating light sources

When evaluating light sources using TM-30-20, it is crucial to consider both the Rf and Rg metrics, along with the Color Vector Graph and Gamut Index. These metrics provide a comprehensive understanding of color rendering performance and allow for informed decision-making.

By analyzing the Color Vector Graph, designers can identify any specific color areas that may require adjustment or improvement. The Gamut Index helps assess the overall color saturation and intensity, ensuring that the lighting solution aligns with the desired visual impact.

Collaborating with manufacturers

As TM-30-20 gains wider adoption, it is essential for designers to collaborate with lighting manufacturers to ensure the availability of light sources that meet the specified color rendering requirements.

Manufacturers can leverage the insights provided by TM-30-20 to develop and market products that align with different design intents and priority levels.

By closely working with manufacturers, designers can access a wider range of lighting options that deliver the desired color rendering qualities and enhance the overall lighting design.

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