



# SYLVANIA LED Innovations

## Natural LED Light with TruWave Technology™

Natural Light for Natural Living™



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### What is Natural Lighting?

There is no life without light — since the early evolution of humans, we have had an intrinsic affinity to natural sunlight. On a nice day, we like to step out and soak in the sun. When we select clothes or cosmetics, we try to imagine what it would look like in natural light, and if we could, we would try to see them in sunlight to see how they *really* look. Natural Light is the baseline for how things look “normally”. However, since the advent of artificial light, we have got used to compromising on what is normal or natural. Such compromises are no longer necessary with the launch of Natural Series™ offered by LEDVANCE using its best in class TruWave Technology™.

Before we drill down in to LEDVANCE’s latest innovation, let us look at what we mean by natural lighting — “Natural Lighting” refers to artificial lighting that is specifically designed to replicate full-spectrum daylight with no missing wavelengths between 380nm and 770nm. It is widely accepted that full-spectrum light sources provide illumination with superior color quality (Figure 1).

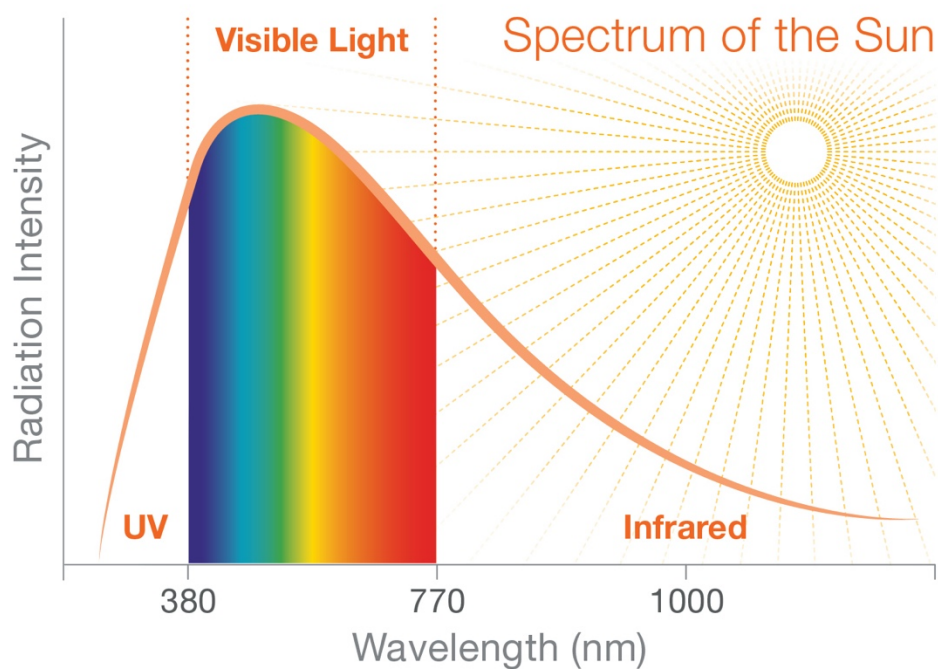


Figure 1: Spectrum of the Sun

The “color” of any object is a function both of the light spectrum of the source and the wavelengths the object reflects. In general, the eye sees light that reflects from the surfaces of an object and so the color appearance of any object will be the same as the emission spectrum of the light source minus whatever wavelengths of light are absorbed or transmitted by the object (Figure 2). High quality natural light provides artificial lighting with spectral characteristics simulating familiar lighting conditions (e.g. daylight), such that the “color rendering” of most ordinary objects appears authentic.

## Effect of Incident Spectrum on Color Rendering

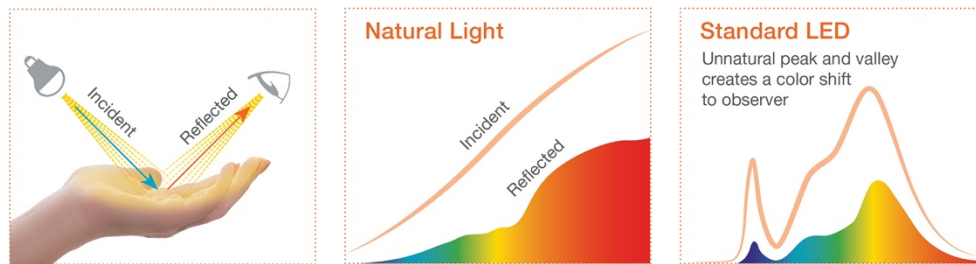


Figure 2: Effect of Incident Spectrum on Color Rendering

When a light source has gaps in its spectrum, the reflected color spectrum of the object is incomplete relative to viewing the object under full-spectrum illumination. Therefore, the reflected light will also have those bands missing as we see in Figure 2. For instance, skin tones look pallid where the light source has high blue content and flushed where the light source has too much red light. In another example, bright red strawberries (Figure 3, center) look brownish, or otherwise unnatural in the absence of a natural balance of wavelengths in the light source.

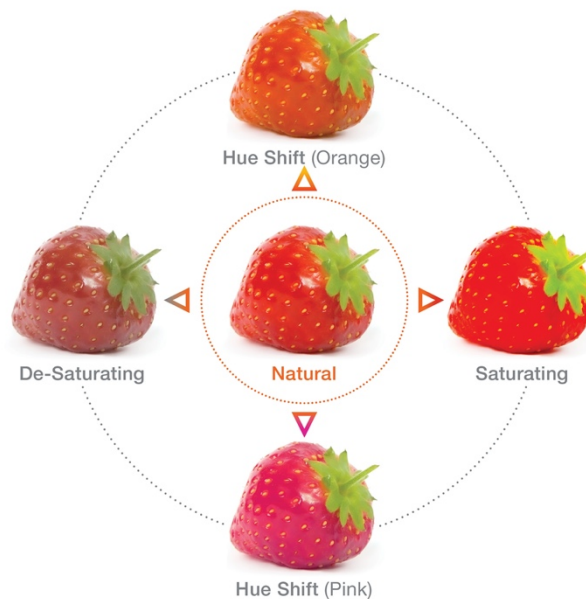


Figure 3: Effect of Unnatural Light on Color Rendering

Natural Light also implies that the distribution of wavelengths within the visible region of the spectrum be comparable to a daylight spectrum. Although an incandescent lamp has a full and continuous spectrum, it inherently provides a warm white light dominated by red making it more like a typical sunset spectrum. Some specialty fluorescent lamps claiming to deliver full spectrum, use a blend of phosphors stimulated by UV, to produce light at the specified color temperature. Inevitably, this is achieved by compromising either efficacy or color rendering. On the other hand, high quality LEDs offer a relatively balanced solution of light quality and high efficiency with minimum compromise. The spectrum of daylight is of course a moving target, depending principally on latitude, season of the year, time of day, and local weather conditions. However, on average, daylight is much more balanced and typical of natural light.



## Why is there new interest in Natural Lighting?

Full-spectrum phosphor lamps as discussed above have been a niche product category for a long time, catering mainly to specialty commercial applications with high color rendering requirements and for well-being applications. Natural light improves the sense of well-being in humans who prefer the balanced glow of sunlight. It is also preferred because of the accuracy with which objects are perceived, whether they be textiles or produce in stores, or skin tones, furniture, or paint in a home. There are also ongoing studies showing benefits for reading, concentration, and alertness in educational and work settings. Recent advances in LED lighting have catalyzed further interest in these application areas. With LEDs' ability to effectively optimize the spectrum, this desire for natural light can finally be realized while still maintaining high energy efficiency.

We will discuss Color Rendering Index (CRI, scale 0-100) further, but put simply, it is a measure of how an object looks under artificial light relative to sunlight. A CRI of 100, implies the object's appearance under a lamp exactly matches its appearance under the midday sun. Today's full-spectrum LED lamps are more than 5 times more efficient than incandescent products while still maintaining better than 90 CRI. Full-spectrum LED products provide an upgrade in luminous efficacy and lifetime, while still delivering a highly optimized color rendering. Let us discuss some examples where natural light really provides superior benefits.

**High CRI applications** Some commercial lighting applications, e.g. office illumination, may be adequately served with 80 CRI. However, many applications have a strong requirement for color fidelity. For example, retail display lighting, museum lighting and photography, video and stage lighting allow no compromise on CRI. An additional feature of full-spectrum LED products is the ability to be designed for higher correlated color temperature ranges (CCT), whereas incandescent full-spectrum products are typically limited to low CCT illumination.

**Well-being applications** Our understanding of the physiological and psychological benefits of light is based on the belief that humans have evolved over millions of years with only sunlight. Yet, the science about the subtleties of our biological needs is still evolving. For example, the existence of specialized photosensitive retinal cells governing the circadian cycle, very distinct from the rods and cones responsible for vision, was only conclusively shown in 2002 [1,2]! Surveys show that people spend an average of 87% of their time in enclosed buildings [3]. This represents an enormous fraction of our lives under artificial lighting, and so it is especially important that the lighting provides the benefits of natural light such as reduced eye strain and improved sleep wake cycles.

While work on establishing well-being benefits of full spectrum lighting is still ongoing, there is increasing scientific support for the use of specific wavelengths of blue light to regulate the human circadian system in an effort to improve sleep-wake cycles, consequently providing a wide range of health and productivity benefits [4]. This generally involves the controlled inclusion of some blue light in the early part of the day and controlled exclusion of excessive blue in the later part of the day and evening, in effect mimicking the transitions of natural daylight.

Some instances where controlled exposure to full-spectrum artificial Natural Lighting is beneficial are

- Education spaces where students can benefit from reduced eyestrain and improved concentration [5-7]
- Business and vacation travelers seeking to adapt quickly to new time zones and reduced jet lag
- Night shift workers using artificial natural lighting to help maintain alertness
- For combating SAD (seasonal affective disorder) during winter for people in northern latitudes
- Residential lighting requiring a combination of high color rendering and well-being benefits
- Office and factory workers with long hours under artificial light desiring improved sleep-wake cycles [8,9]

## What makes LED Lighting different from traditional lighting?

The first few million years of illumination history is the story of bona fide natural light. Later, incandescent lighting forever changed society's daily activity structure by extending work hours into the nights, while fluorescent

lighting led to the use of blended phosphors to create specific lighting spectra. However, both these light sources have limitations which are overcome by LED technology, specifically:

- **Energy Saving** — LED Lighting is very efficient since it is based on semiconductor technology. Unlike traditional sources where light is a *secondary* outcome of heat or plasma creation, LEDs are solid-state devices which *directly* convert electrons to photons. To provide a sense of scale, LEDs can produce over 100 lumens per watt relative to incandescent lamps which deliver about 10 lumens per watt.
- **Long life** — LEDs being solid-state electronic devices have very long lifetimes. Quality LED lamps and luminaires can maintain over 70% of its initial light output for 50,000 to 100,000 hours (compared to 1,000 hours for incandescent and 10,000 for compact fluorescent lamps)
- **Design Flexibility** — Since LEDs are based on semiconductor chips, they are inherently of small size and so LED lamps and luminaires can readily provide high design flexibility, including spot lighting for focused light and distributed light in diffuse lighting applications.

## LEDVANCE's innovation for Natural Lighting from LEDs

Most traditional lighting, including conventional LED lighting produces “daylight” only with regard to illumination color (Correlated Color Temperature — CCT) and *adequate* color rendering (Color rendering Index — CRI), in an effort to maximize luminous efficacy (lumens per watt). LEDVANCE has launched its innovative product line Natural Series™ based on SYLVANIA TruWave Technology™. This innovative technology delivers a continuous full spectrum to achieve superior color rendering while *simultaneously* delivering the comforting qualities of natural daylight. Some of these visual comfort qualities can be more specifically achieved by avoiding typical flaws of artificial lighting systems. For example, products based on SYLVANIA TruWave Technology™ are designed to provide a lighting experience that minimize glare and eliminate flicker, are dimmable and have a higher than 90 CRI *without compromising high efficacy*.

SYLVANIA TruWave technology™ closely mimics the natural light spectrum and provides a comfortable, dimmable light that reduces eye strain and improves sleep-wake cycles while rendering colors as naturally as possible.

### Highlights of the advanced technologies in SYLVANIA TruWave™ products

**TruWave Technology™** Patented SYLVANIA TruWave Technology™ utilizes multiple quantum wells to produce a broad blue emission and hence a LED configuration which delivers a fuller composite spectrum (Figure 4). The result is a superior match to continuous spectrum lighting, specifically natural daylight. Not only does this enable a more natural color rendering, but it also avoids potentially negative consequences of a single intense blue wavelength.

**Color Quality** Color quality is generally associated with a full spectrum light source and high CRI and ideal CCT. Unfortunately, many LED products have poor color quality due to trade-offs made by manufacturers to boost efficiency at the expense of color rendering or color accuracy. Such products therefore have a large single blue wavelength to increase the power efficiency of the product. However, as we have discussed, the blue in the spectrum has to be optimized for human well-being and visual ease. SYLVANIA TruWave Technology™ creates a highly optimized spectrum by reducing intense blue light and delivering a comfortable spectrum closer to that of natural light.

**Full Spectrum** Full spectrums are achieved by combining single colors such that they produce the entire visible spectrum. The most common type of full-spectrum LED lamps and luminaires use efficient blue LEDs to excite green, yellow, and red emitting phosphors. The unique innovation in SYLVANIA TruWave Technology™ involves the use of a patented LED design which generates a blue emission with reduced intensity and wide spectral range to produce a broader blue distribution, thus delivering a superior match to natural daylight.

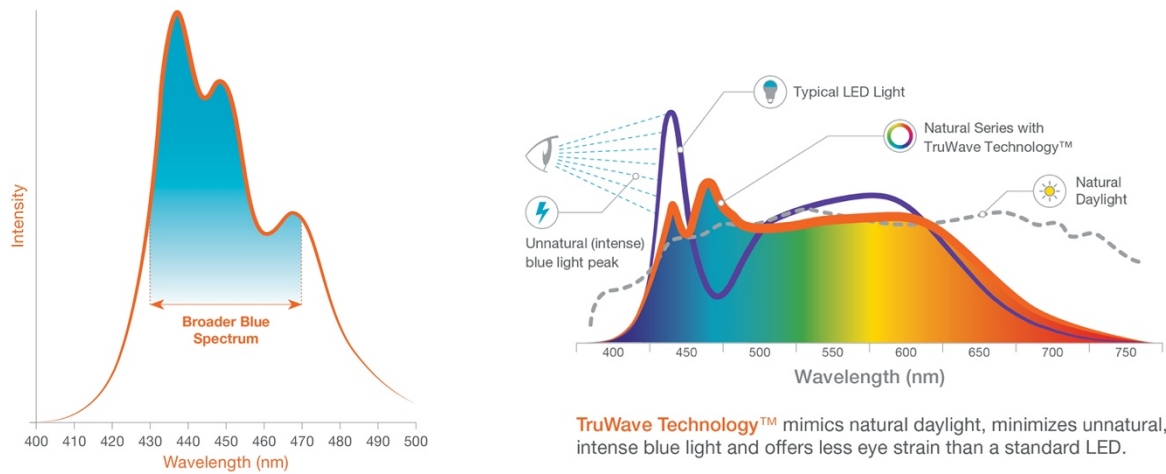


Figure 4: TruWave Technology™ Broad Blue Emission and Full Color Spectrum

**Dimmability** LEDs are inherently easily dimmable because they operate on low voltage DC current and are very responsive to voltage variations. The time lag between voltage signal and light output is about 10 nanoseconds in a typical LED, therefore they can be controlled and modulated at speeds faster than the human eye can detect! A common problem with many commercial lamps and luminaires is the onset of flicker at low light output. While LED technology can never be totally flicker free, SYLVANIA Natural Series™ provides the best low flicker performance and excellent dimmability, ensuring a superior experience and visual comfort in a wide range of applications.

**Flicker** A related performance criterion is flicker, which is the perception of illumination not being constant in time, often caused by a poorly designed or malfunctioning electrical power supply. Most people are familiar with fluorescent lighting occasionally exhibiting this type of fast pulsing effect. SYLVANIA TruWave Technology™ can provide smooth dimming over a large range of luminous intensity *without spectral changes* and delivers a high-quality illumination that is perceived to be constant in time with minimal flicker.

**Glare** is generally the uncomfortable occurrence of too much light delivered to the eye, sometimes caused by direct line of sight to a relatively small sized light source, or sometimes indirectly by a concentrated reflection from a surface. Also, blue light scatters more than longer wavelengths like green, yellow and red. This is of course why the sky looks blue on a clear sunny day, but in a similar way, increased scattering of blue light can disrupt visual clarity for many people. TruWave Technology™ innovations include reduced intensity blue spectrum that closely matches natural light. As a result, SYLVANIA Natural Series™ delivers reduced eye strain, superior comfort and best in class visual experience.

### What best practices contribute to high quality natural lighting products?

Let us examine commonly used objective measures of high-quality lighting and how TruWave Technology™ performs.

**CRI and TM30** CRI is a widely used color accuracy standard which compares objects under the light source with their appearance under a reference source such as sunlight. TM30 is a color quality standard which remedies some of the flaws in the use of CRI by defining a measure of color fidelity and gamut relative to a reference illuminant (or daylight) [10-11]. Since fidelity is measured using 99 test samples representing a large variety of objects, this is a more comprehensive measure of color quality. Fidelity ( $R_f$ ) and gamut ( $R_g$ ) measurements can be considered to represent the “naturalness” of how colors are rendered. In graphical form (Figure 5 — color vector graph and comparison with a standard CRI 80 lamp), the performance of a lamp is demonstrated by the closeness of the red circle to the black circle (99 test samples under natural light). Ideally, for a natural appearance, the  $R_f$  and  $R_g$  should

be 100, indicating no deviation from the natural light appearance. SYLVANIA Natural Series™ products have a CRI of greater than 90 and an excellent  $R_f$  of 94 and near perfect  $R_g$  of 98, both at a CCT of 2700K. Visually and intuitively, in Figure 5, this outstanding performance is confirmed by the near perfect match of the natural light reference circle (black) and the SYLVANIA TruWave™ circle (red). TM30 performance demonstrates conclusively that SYLVANIA TruWave™ delivers a truly natural appearance!

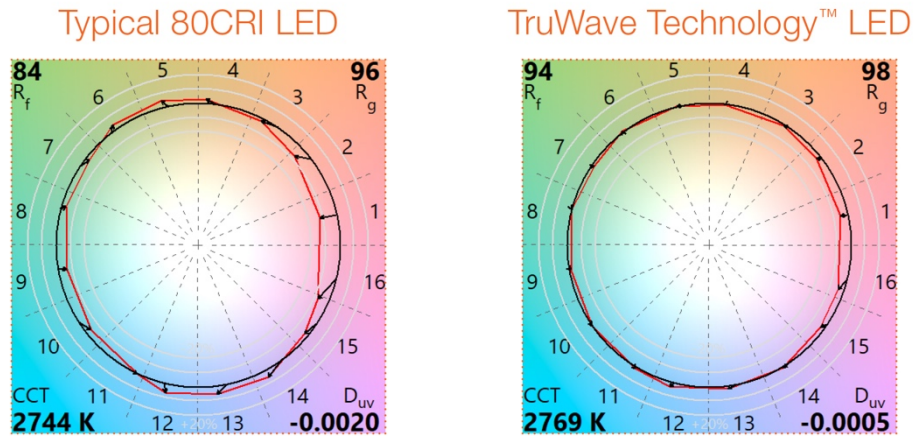


Figure 5: TM30 Color Vector Graph Comparison

**The WELL Building Standard®** is another relevant prescription for lighting requirements in buildings [12]. The WELL Building requirements for Circadian Lighting Design include four sections which separately specify the amount and scheduling of light Intensity (which can include contributions from daylight) in Work Areas, Living Environments, Breakrooms and Learning Areas. The Living Environments sections also specifies not-to-exceed levels of melanopic light intensity during nighttime. Lighting in offices and other similar workplaces may also benefit from the well-being outcomes of natural light. Recent research within the smart-buildings community finds that 90% of office business costs are related to employees, i.e. salaries, benefits, etc. [13]. Only 1% goes for energy, and of that only half (0.5%) for electricity [14]. Lighting solutions that increase energy efficiency only leverage the 0.5% of costs. However, lighting solutions that increase employee well-being and productivity will target 90% of costs. SYLVANIA Natural Series™ provide value well beyond what simply switching to LEDs can provide in meeting WELL Building requirements.

**Circadian Action Factor** Another useful metric for characterizing Natural Lighting is the circadian action factor (CAF) which relates to the circadian effectiveness of the light source on the human circadian cycle, just as the luminous efficacy refers to the efficiency of the lamp in producing light [15-17]. CAF is a ratio of the circadian efficacy relative to the luminous efficacy and indicates the amount of circadian stimulation per lumen. A 2018 article in the Harvard Business Review discusses a “Future Workplace Wellbeing Study” survey of over 1600 office employees across the US and Canada finding that the most desired attribute of the workplace environment was “natural light and views of the outdoors” [18]. SYLVANIA TruWave Technology™ produces light whose CAF matches closely with the CAF of natural light minimizing the risks associated with common engineered light sources.

**Circadian Stimulus** An alternative to CAF is the Circadian Stimulus (CS). Melatonin, a chemical produced in the body during the night and suppressed by daylight, determines the human sleep-wake or circadian cycle. The CS is an application dependent measure of the impact of light on the circadian cycle via melatonin suppression (range: 0.1 to 0.7 for negligible to maximum impact). The CS considers not only light levels, spectrum, light history but also the timing and the duration of the light. Experts recommend a CS of 0.3 on waking, by exposure to daylight for a balanced circadian cycle through the day [19-22]. Sylvania Natural Series™ provides superior support for sleep-wake cycles by helping deliver a CS close to that of natural light.

**Lighting System Quality** While SYLVANIA TruWave Technology™ provides a best in class light source, quality lighting necessarily goes beyond the light source. In fact, a total system quality requires a more complete effort including a focus on high quality electronics and drivers (often a major failure point) to eliminate flicker, and ensure smooth dimming, as well as good optical design for glare free performance and optimal light distribution. Furthermore, the light fixture needs to be designed to deliver the light where required. SYLVANIA Natural Series™ products provide the ideal light source and luminaires for superior lighting systems.

## **SYLVANIA TruWave Technology™ is ideal for several applications**

There are numerous applications where SYLVANIA TruWave Technology™ provides great value with its innovative approach by closely matching natural light. TruWave™ improves a sense of well-being and comfort, by offering light quality that humans generally prefer, reduces eye strain, and renders colors with a more authentic quality. Also, it delivers a well-balanced color spectrum which is conducive to a healthy sleep-wake cycle.

**Residential lighting** is an application that combines preferences for high color rendering with well-being aspects. SYLVANIA Natural Series™ now provide a superior balanced spectrum using vastly more efficient LEDs. A well-balanced simulated daylight spectrum provides a natural amount of blue light circadian stimulus, particularly in residential applications, for mornings before school and work. SYLVANIA TruWave™ innovations provide simple, easy to use products for the home that provide the best balance of wavelengths for a comfortable light quality which smoothly extends the natural light feeling into the night while promoting a sense of well-being in the home.

**Retail** is a market that explicitly realizes a return on investment based on successful lighting solutions. Color rendering is a primary concern for many retail applications. In particular, it is imperative that customers evaluate colors, textures, and finish of merchandise accurately, particularly for clothing and home furnishings such as furniture, carpets, and paint colors. Additionally, rendering of hair color and skin tones in the cosmetic sections is a critical requirement. Cosmetics, and related products rely heavily on lighting with high color rendering over a wide spectral range. SYLVANIA Natural Series™ has the full-spectrum attributes to deliver excellent color rendering where needed. Further, and in contrast to fluorescent and compact fluorescent products, these products can be designed into both spot lighting applications as well as diffuse and ambient lighting products.

**Office** and other workplace environments combine a wide range of lighting concerns especially the need for low eyestrain, high comfort, and minimal flicker. Lighting in offices and similar workplaces may also gain from well-being benefits of natural lighting such as offered by SYLVANIA TruWave Technology™. Lighting solutions that increase employee well-being and productivity have a potentially large ROI for businesses, and of course significant benefits for the employees themselves. Compliance with WELL Building standards can increase employee morale and retention rates. SYLVANIA Natural Series™ rises to meet these needs relying on a patented LED design which mitigates issues of glare and the intense blue light that often arises from conventional LED products. Furthermore, it provides good dimmability, low flicker, and a natural light spectrum resulting in a comfortable experience while reducing eyestrain.

**Education** environments have many of the same requirements as offices and other workplaces. Education lighting designers increasingly seek improvements in productivity and reduced fatigue. In fact, the WELL Building standards includes a lighting feature for Learning Areas. Various recent studies describe efforts to demonstrate benefits of special LED lighting in educational environments. In comparison to standard lighting conditions, students showed faster cognitive processing speed and better concentration under certain conditions [23,24]. Natural Series™ products offer full-spectrum natural light with minimal flicker and can be beneficially installed in schools, classrooms, and other learning areas.



**Airport lounges and public areas** can be a subset of the general hospitality market. Airports in particular encompass a complex variety of requirements. Travelers need an environment where they can relax, work, socialize and in many cases adjust to new time zones, all while battling the stresses of travel. SYLVANIA TruWave™ lighting can play an important role in creating both a welcoming feeling and delivering physiological well-being benefits and soothing a stressed traveling public.

## Conclusion

LED upgrades are typically driven by a perception that light is a commodity to be obtained at the lowest cost. This places an emphasis on energy efficiency and energy cost savings, which is relevant but should not result in missed opportunities to cost-effectively provide additional value by improving the quality of light overall. While light is indeed a commodity, *lighting* — the application of light to spaces — can be an asset, supporting design goals by providing accurate colors, visual comfort, and enhanced space perception. These are worthy investments that can produce tangible value and should be carefully considered.

A sensible approach is a broad, balanced color spectrum, like natural light, which still remains the ideal light source. Developed by LEDVANCE, the **SYLVANIA Natural Series™** LED lighting portfolio with TruWave Technology™ brings the benefits of natural light inside commercial and residential spaces. This innovative LED portfolio offers the best alternative to natural light by mimicking the natural light spectrum, thanks to TruWave Technology™. With this capability, the Natural Series™ portfolio:

- Provides a broad spectrum without sacrificing light output or adding significant cost
- Controls blue wavelengths for lower glare and reduced eye strain
- Provides natural red colors to make spaces and flesh tones both accurate and vibrant
- Supports an improved sleep-wake cycle for occupants
- Offers a well-balanced spectrum whilst maintaining high energy efficiency
- Delivers clean, natural light for seeing realistic, vivid colors

\*The SYLVANIA LED Innovations White Paper maybe amended by LEDVANCE based on latest technology developments that will be available from Research & Development, Product and LED Chip Technology, Lighting and Building Standards and Regulations

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