# UNDERSTANDING POULTRY LIGHTING:

## A Guide to LED Bulbs and Other Sources of Light for Egg Producers

### INTRODUCTION

Light is an essential aspect of poultry production. In most housing systems, artificial light is utilized to maximize production in pullets, layers and breeders. Today, a variety of different bulbs are available to illuminate the inside of a poultry house, all of which have benefits and shortcomings. Understanding the different lighting options available for poultry, as well as the terminology and management of light, is essential to achieve the best production.

### UNDERSTANDING POULTRY LIGHT BIOLOGY AND ENVIRONMENT

Light is critical for egg production and pullet growth. Domestic poultry see and respond to a different range of light color spectrum and have different spectral intensity responses than humans. While humans respond to light from around 400–750 nm, chickens can see UV-A light (315–400 nm) in addition to 400–750 nm. Additionally, the magnitude of sensitivity for red and blue spectra is much higher for chickens with additional peaks of light sensitivity around 480 nm and 630 nm.

### LIGHTING TERMINOLOGY

**Photoperiod:** Duration of light in a 24-hour period.

**Luminous flux:** Total perceived power of light produced by the light source. The unit is Lumen (lm). The prefix "luminous" always indicates that the measured unit is adjusted by luminosity function or human eye sensitivity. The prefix "Visible Radiant" or "Radiant" indicates that the measured unit is in "raw" form (for example - total photons) independent of particular visual system.

**Luminous intensity:** Power emitted by a light source into directional solid angle. The unit is Candela (cd).

**Illuminance:** Total luminous flux on a surface. The unit is lux (lx) and the non-metric unit is foot-candle (fc).

**Clux or galliux:** Total radiant flux incident on a surface adjusted by color (measured in nanometer [nm]) sensitivity curve of chickens (*Gallus domesticus*). The unit is Clux (cLx).

**Visible light spectrum:** Portion of the electromagnetic spectrum that is visible to the human eye or animal eye. Spectrum wavelength (nm) determines the color of the light (430nm to 490nm is blue color).

**Ultraviolet (UV):** Electromagnetic radiation from 10 nm to 400 nm.

**Infrared light (IR):** Electromagnetic radiation from 700 nm to 1,000,000 nm (1 mm).

**Photopic spectral sensitivity:** Color sensitivity or sensitivity to light under bright conditions.

**Color rendering index:** A measure of the ability of a light source to reveal the colors of an object in comparison to ideal light source. Incandescent light can be considered ideal light source.

**Chromaticity:** The objective measurement of the color of a light source independent of the illuminance.

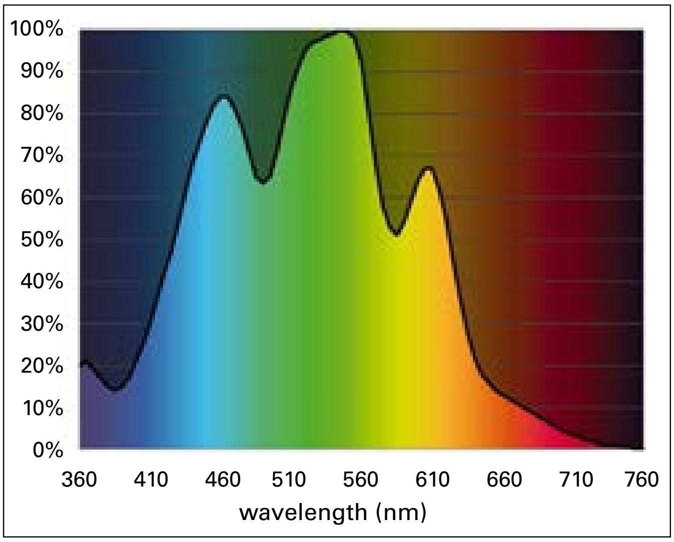


*Figure 1. Domestic fowl photopic spectral response.*

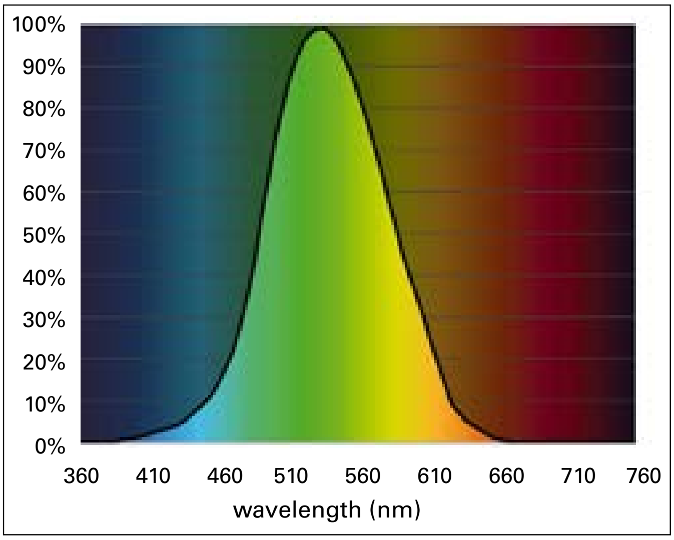


*Figure 2. Human photopic spectral response (CIE 1978).*

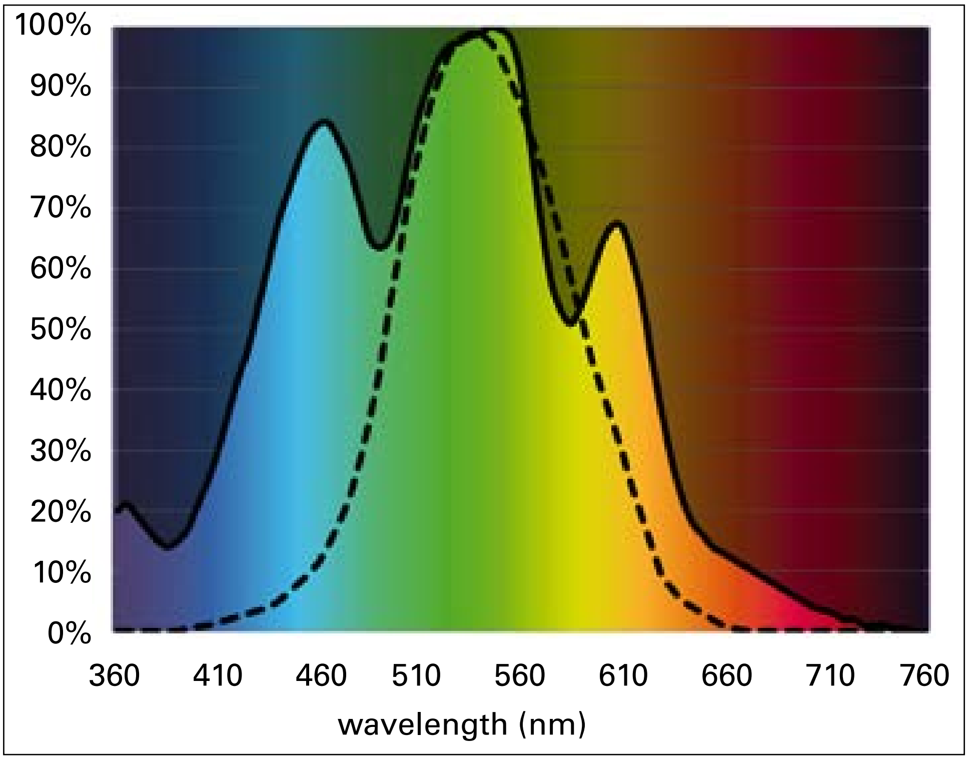


*Figure 3. Comparison of human and chicken photopic vision.*

### *Understanding the Difference between Lux and Clux*

While peak lux can be assessed at any wavelength, the International Commission on Illumination (CIE) standard for measuring light intensity is set at the peak human response of 550–560 nm. Chickens have three photopic spectral peaks, so additional calculations utilizing the poultry-specific peaks are required to measure these clux. Depending on the light source and peak spectrum, clux can be up to 50% or higher in light intensity than lux.

Understanding the difference between lux and clux provides a more accurate selection of light bulbs for the producer and allows them to recognize the limitations of traditional light meters. While using a traditional light meter can be an indicator of light intensity in a house, there will always be a difference between lux and clux.

### *Poultry Light Biology*

Chickens detect light not only through the retinal cone receptors in the eyes, but also via extra retinal photoreceptors in the pineal gland and the hypothalamic gland. The response to light controls the circadian rhythm, a 24-hour cycle in the bird's hormonal and behavioral aspects. Humans are trichromatic and have retinal cones that can determine red, green and blue. Chickens are tetrachromatic, with an additional double cone whose function may be related to tracking movement (4).

In poultry, red light is vital for stimulating sexual maturity and egg production. Birds exposed to red light versus blue, green or white light consistently have higher egg production than the other color groups. Red light is able to penetrate the skull to stimulate the extra retinal photoreceptors. Red light (around 650 nm) penetrates the skull and brain (hypothalamus) four to 50 times more efficiently than blue, green and yellow-orange light (2). The hypothalmus is important in regulating the production of hormones important for egg production.

### *Light Environments*

Chickens are affected by the duration, intensity and spectrum of light. Light can be utilized as a management tool to help optimize pullet growth, age of sexual maturity, egg weight and egg production in laying hens in a variety of environments.

**Duration** – As a general rule, decreasing light duration is utilized for growing pullets and increasing light duration is used to stimulate layers. Light stimulation (usually an increase of as little as one hour) has an immediate effect on the production of reproductive hormones. The standard level of light for maximum production is 16 hours. It is ideal to reach 16 hours of light by 30–35 weeks to help prolong peak production.

**Spectrum** – Understanding the color spectrum given off by a light source will assist producers in selecting a light bulb which can deliver the proper amounts of red, green and blue light. Light bulb color can be expressed in degrees Kelvin (K) and color rendering index (CRI). However, neither of these measurements expresses the spectral peak intensity in the red, green, and blue spectra that are important for poultry growth and production. Research on broilers has shown that blue and green LED lights enhance growth (5). Research on layer pullets indicates that LED lights with a greater portion of blue and green spectra result in better body weights and uniformity compared to incandescent bulbs, although more data is needed (Settar, unpublished data). Overall, pullets may be reared with warm or cool lights, but laying hens should have lights with a sufficient red spectrum (3) (2700K–3000K). Light bulb manufacturers usually provide information on degrees Kelvin, or a spectrometer can be used.

**Intensity** – Light intensity, measured in lux, clux or foot candles, is also important for poultry production. In general, light intensity below 5 lux (0.5 fc) is too dark to stimulate proper growth and production, while higher light intensity (above 50 lux/5 fc) may cause nervousness and aberrant behavior. The standard recommendation for growing pullets is to brood for 2 to 3 weeks at 30–50 lux (3–5 fc), and then dim to 10–15 lux (1–1.5 fc) until 14 weeks. Two weeks prior to the transfer, gradually increase the light intensity to match the levels in the layer house. Laying hens should be kept at an average of 30 lux (3 fc) at the level of the feed trough.

Maintaining uniform light intensity in a modern poultry facility can be difficult. To measure light distribution in conventional cage or colony houses with manure belts, it is ideal to take a measurement at the feed trough every 25 cm (1 foot) between lights and at every level. This will typically require between 30 and 100 light readings to accurately assess the light distribution. In floor houses, measure at the wall, at feeder and drinker lines beneath the lights and 2–3 times in between lights for a total of 10 to 50 measurements.

In open-sided houses, use window shades and curtains to prevent direct sunlight from coming into the house. Even with these interventions, the light intensity in open houses can easily reach above 1000 lux (93 fc).

## UNDERSTANDING LIGHT SPECTRUM, CHROMATICITY AND COLOR RENDERING INDEX

Light is the visible part of the electromagnetic spectrum. Understanding the impact light spectrum has on poultry production is critical for selecting the right bulb.

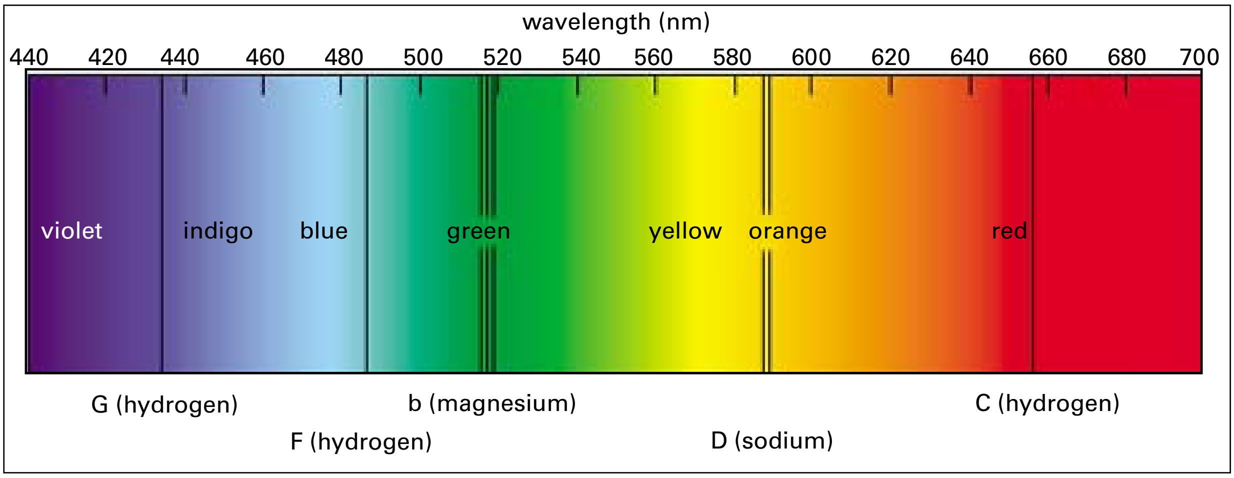


*Figure 4. Visible light spectrum.*

### *Chromaticity or Correlated Color Temperature (CCT)*

Chromaticity measures the relative warmness or coolness of light, and is expressed in degrees Kelvin (K). While originally developed for incandescent lights, chromaticity gives an estimation of the dominant spectra in a given light source; however, chromaticity does not give information about the relative color peaks or balance of spectrum.

**> 4000K**: cool, dominant blue spectrum

**3500K:** neutral and balanced with red, green and blue spectra

**< 3000K**: warm, dominant red spectrum

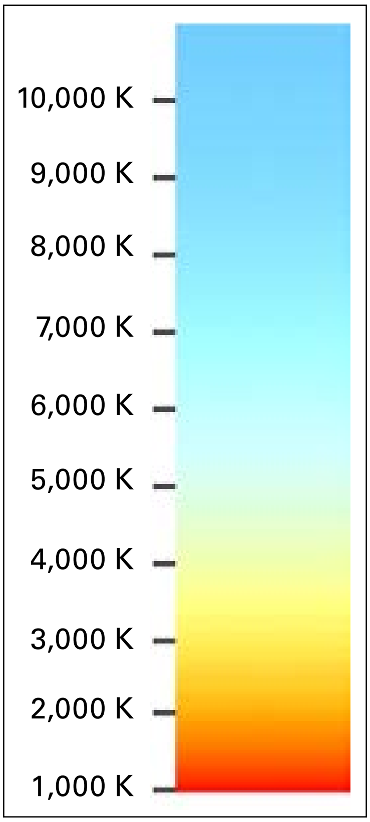


*Figure 5. Kelvin color temperature scale.*

### *Color Rendering Index (CRI)*

The color rendering index measures how an artificial light source displays the color of an object compared to the color of that object in natural light. This measure is important for human perception and comfort in a light environment. CRI is measured on a scale of 0–100, with 100 being the closest to natural light. The higher the CRI, the closer the artificial light source is to displaying colors accurately. Overall, CRI differences less than 5 (i.e. 80 to 84) are not noticeable to the human eye. The CRI system was originally developed for incandescent lights and does not correlate as well with compact fluorescent light (CFL) or LED lights.

A general scale for evaluating lights using CRI values is (1):

- < 50: Poor
- 50–70: Fair
- 70–80: Good
- 80–100: Best

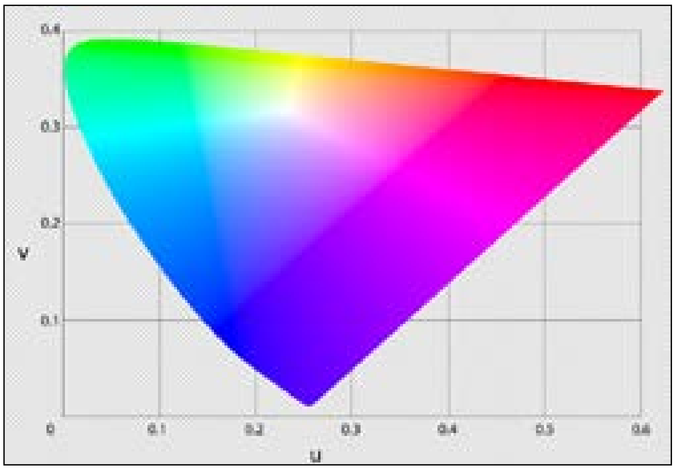

*Figure 6. Color rendering image chart.*

## AVAILABLE LIGHT SOURCES

Many different types of light sources are utilized in the poultry industry, ranging from open houses under the influence of the sun to the most technologically advanced layer houses with the newest equipment without exterior light influence. Understanding the spectral composition of different light sources is important for selection amongst multiple lighting types.

### *Sunlight*

**Benefits**

- In equatorial regions, light from the sun is consistent from season to season.
- Full spectrum light ranging from UV to IR
- The response to sunlight changes from day to day and season to season are naturally inherent in both domestic and wild fowl.
- Poultry houses designed to utilize natural daylight may require little or no artificial light, saving on energy costs.

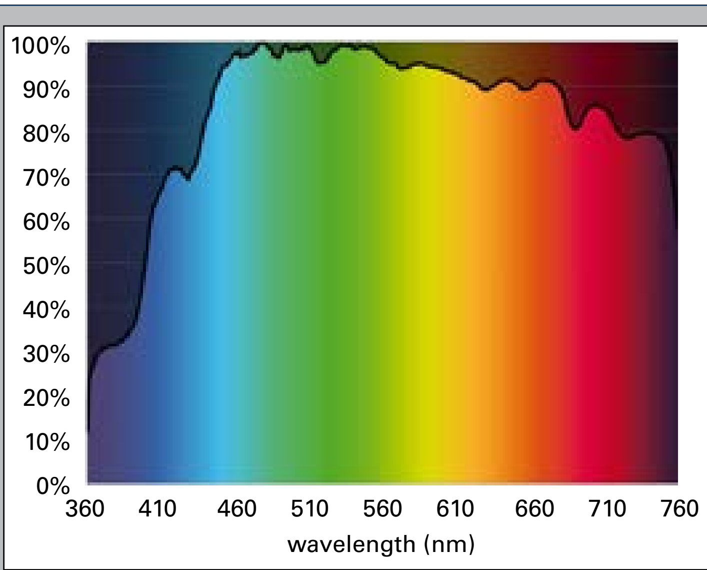


*Figure 7. Spectrum of sunlight at noon.*

**Shortcomings**

- The spectral composition and intensity of sunlight changes from dawn to noon to dusk, from season to season, sunrise to sunset, and with cloud cover.
- Light intensity will change throughout the day as light will come in from different areas of the house.
- Light intensity is much higher from the sun than an artificial bulb, and overcoming seasonal day length changes can be difficult. A bright sunny day can be 60,000–100,000 lux (6,000–10,000 fc).
- High light intensity may cause aberrant behaviors such as nervousness, feather pulling, pecking and cannibalism.

### *Incandescent Lights (INC)*

**Benefits**

- Inexpensive
- Good red spectrum output
- Excellent light distribution
- Quick to turn on
- No difference in performance when used in cold weather

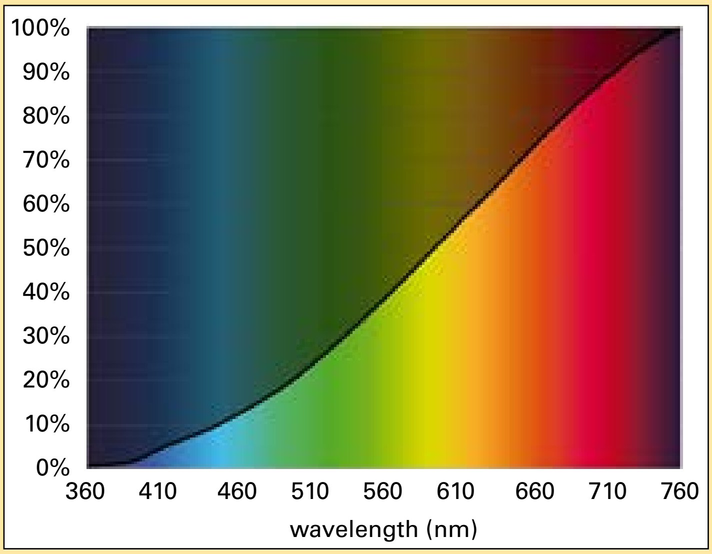


*Figure 8. Spectrum of incandescent light.*

**Shortcomings**

- Short lifespan and must be frequently replaced
- Usually constructed of metal and glass and are prone to breakage
- More than 90% of the energy used by the bulb goes to heat rather than light.
- Many types of incandescent bulbs do not comply with new energy efficiency standards.

### *Compact Fluorescent Light (CFL)*

**Benefits**

- Energy efficient
- Relatively inexpensive
- Similar color spectra as incandescent bulbs
- Available in both warm and cool spectra (K)
- Proven success in layer and breeder industries

**Shortcomings**

- Contain mercury
- Uncovered spiral tubes may be difficult to clean.
- Made out of metal and glass and are prone to breakage
- Bulbs do not dim well, with the potential to burn out more quickly when dimmed
- While appearing to be white light, CFLs are composed of light spectrum peaks depending on the color spectra phosphors utilized in the bulb.
- Bulbs require several minutes to reach maximum light intensity when turned on.
- Poor performance in cold weather
- Not ideal in situations where light must be turned on and off multiple times per day.
- Requires an electronic ballast to regulate current and voltage supplied to the lamp.

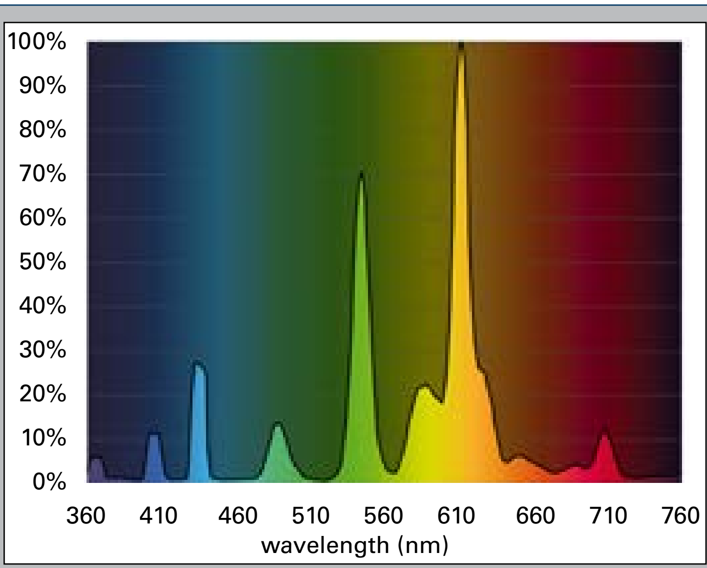


*Figure 9. Spectrum of warm (2700K) fluorescent light.*

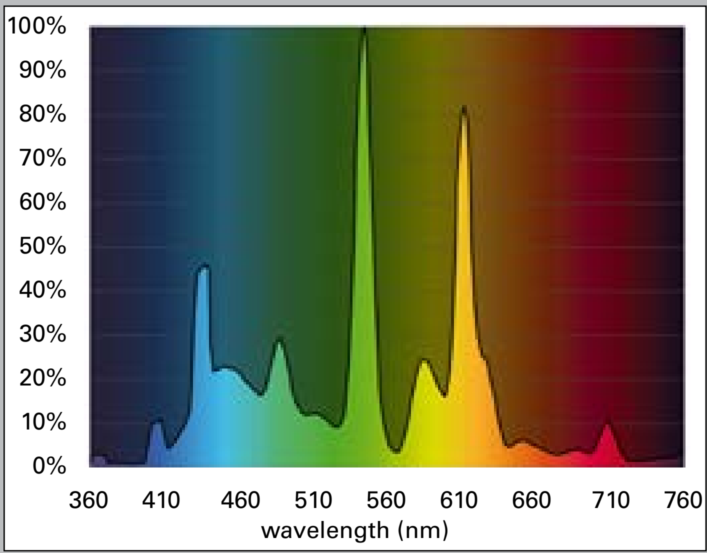


*Figure 10. Spectrum of cool (5000K) fluorescent light.*

### *Linear Fluorescent Light (LFL)*

*Similar advantages and issues as CFL bulbs with some additional information*

**Benefits**

- Dropdown tube lights allow for more uniform light distribution at all vertical levels in a multitiered cage or colony system.
- Casts a broad, even light in floor houses and fewer light fixtures required because of the higher output of a larger tube

**Shortcomings**

- More expensive than CFLs
- Higher levels of glass and hazardous debris if broken
- More difficult to store and transport safely

### *High Pressure Sodium (HPS)*

**Benefit**

- Can be more energy efficient than incandescent bulbs

**Shortcomings**

- Lack sufficient blue and green spectra
- Expensive
- Take a long time to warm up
- Difficult to dim
- Require a ballast

### *Light Emitting Diode (LED)*

**Benefits**

- Provides a full spectrum of light
- Typically the most efficient light bulb measured in lumens per watt
- Because LEDs do not emit infrared radiation (heat), they can be constructed out of non-glass materials that are waterproof and shatterproof.
- Typically manufactured from non-toxic materials
- Can be designed to focus the light onto desired areas
- Color spectrum of the light can be adjusted depending on phosphors used.
- Easier to dim than CFL bulbs
- Dimming can extend bulb's lifespan
- Very long lifespan – up to 10 years at 16 hours per day (50,000 – 60,000 hours)
- Rapidly reaches peak light intensity after being turned on
- Ideal for areas where lights are frequently turned on and off
- Efficient in cold weather with no change in performance

**Shortcomings**

- Expensive
- Must use the proper dimmer, otherwise the light may flicker and burn out more quickly.
- LED light is directional and requires an appropriate lens to focus light, or appropriate diffusers to cover a broader area.
- May need to change wiring in a house to fit the ideal LED electrical specifications.
- The efficiency of heat fins is reduced with dust build-up, poor ventilation around the bulb, or putting the bulb in a "jelly jar" for waterproofing.
- Lights may not burn out after expected lifespan but will be dimmed greater than 70% of original lumen output. As a result, baseline lux testing in the house may be required to determine when bulbs should be changed.
- Cheaper LED lights may not have an appropriate heat sink, spectrum, hardware or warranty for poultry environments.

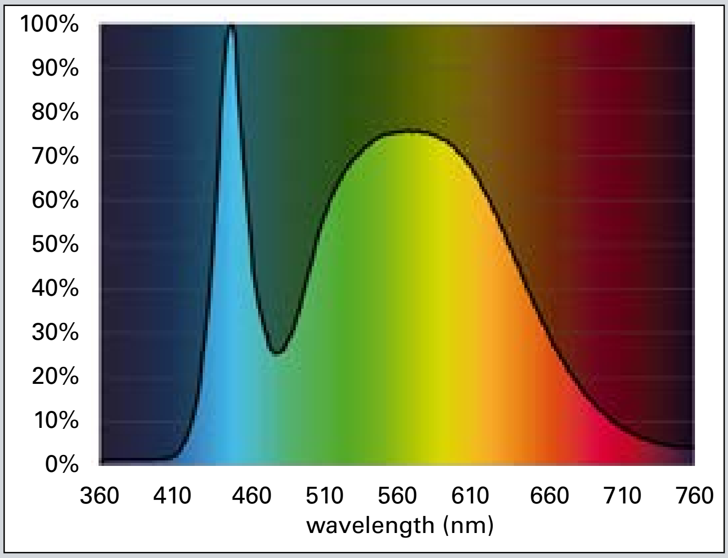


*Figure 11. Spectrum of cool (5000K) LED light.*

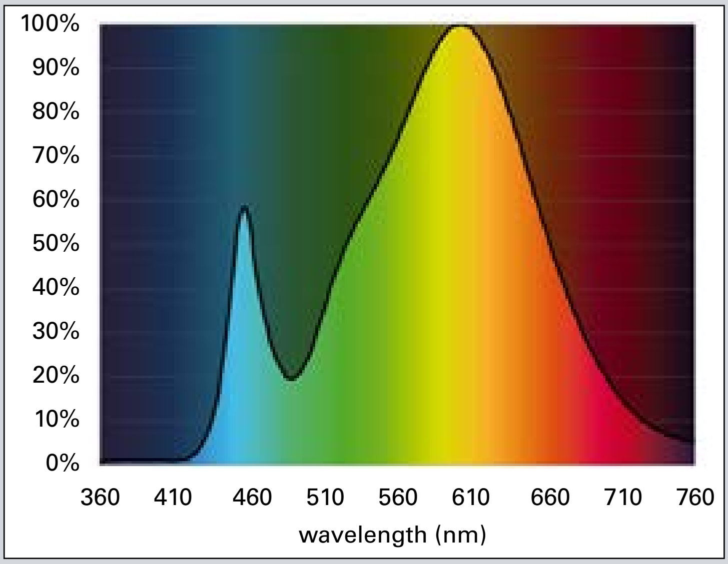


*Figure 12. Spectrum of warm (2700K) LED light.*

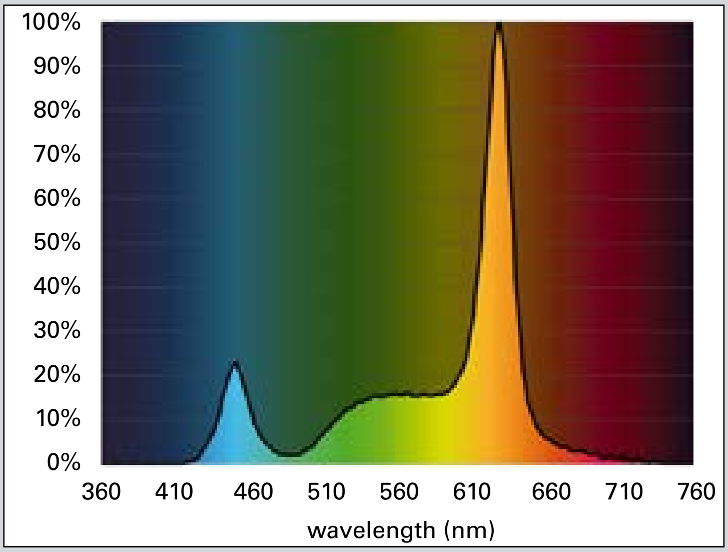


*Figure 13. Full spectrum LED with emphasis on red spectrum.*

## UNDERSTANDING LIGHT INTENSITY MEASUREMENT

Light intensity can be measured in three ways: luminous intensity, luminous flux and luminous power.

**Luminous flux** is the total emitted visible light from a bulb, measured in lumens.

**Luminous intensity** (directional flux) quantifies the luminous flux emitted by a light source in a certain direction, measured in candelas or candles.

**Luminous power** is the luminous flux per area illuminated by the light, measured in lux or foot candles (fc). The calculation is 1 lux = 1 lumen/$m^2$ or 1 lux = 0.0929 fc (lumen/$m^2$). The conversion between the two units is 1 fc = 10.76 lux or 1 lux = 0.0929 fc; this is equal to the conversion between 1 square meter ($m^2$) and 1 square foot ($ft^2$) (i.e. 1 $m^2$ = 10.76 $ft^2$). This means that the same light will be brighter closer to the light source, and dimmer farther away as the beam spreads out.

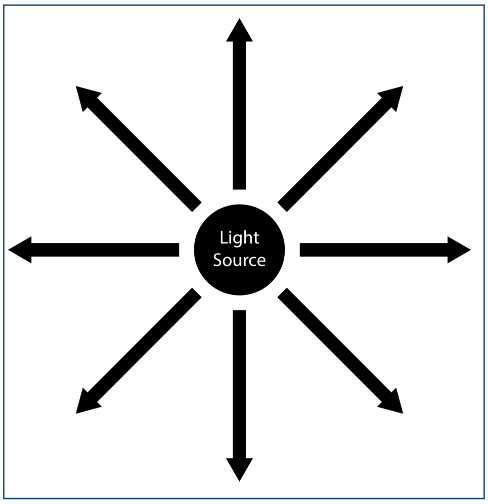


*Figure 14. Demonstration of luminous flux.*

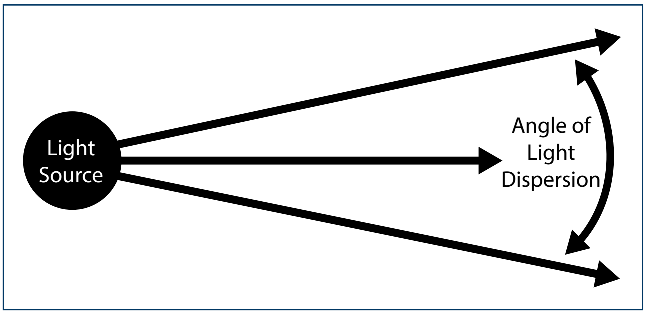


*Figure 15. Demonstration of luminous intensity.*

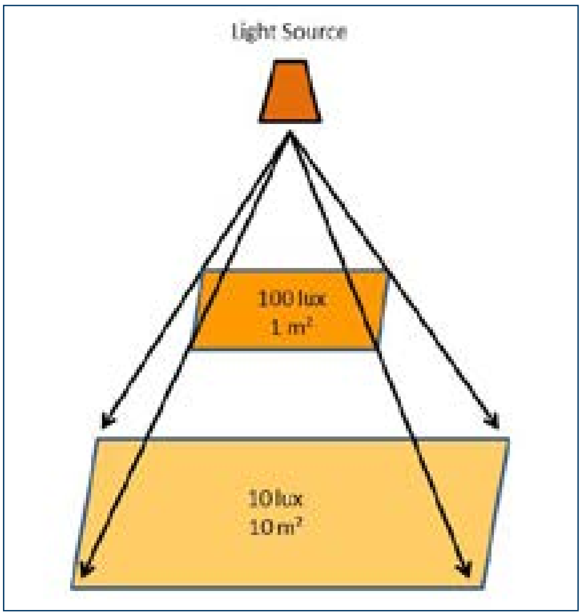


*Figure 16. Demonstration of different light intensities at different distances from the same light source (luminous power).*

### *Light Meters*

Traditional light meters are calibrated for the human spectral response at a white color temperature with a spectrum between 550–560 nm. These light meters are unable to assess blue or red spectrum and cannot calculate the difference in light response between humans and poultry. It is important to be able to observe light intensity in both the visible blue and visible red spectra due to the chicken's wider visible light spectrum.

Ideal light meters for assessing LED bulbs are either poultry-specific light meters or LED-specific light meters. Poultry-specific light meters are able to calculate the effective light intensity as observed by a chicken (clux), while LED-specific light meters are able to analyze the full spectral output of the light for human vision. Only a few companies make poultry-specific light meters, while LED light meters are used by photographers and are available from several sources.

### *Understanding Lumens to Assess a Light Bulb*

With incandescent lights, the luminal output in relation to the wattage of the bulb is consistent across manufacturers. Most traditional incandescent bulbs are sold in 40, 60, 75 and 100-watt versions. With the introduction of compact fluorescent lights and now LED bulbs, most light manufacturers still relate the luminous flux of the bulb back to an incandescent wattage equivalent.

The equivalence between CFL bulbs and incandescent bulbs is valid because both types of bulbs emit light evenly. However, LED light is more directional, and using lumens may not be accurate. Wattage and other factors, such as desired light direction, light color spectrum and intended light usage, should be considered.

Luminous flux assesses the total light output of a bulb without any regard to direction; however, many LED lights can emit light with an angle of dispersion of 30° to 180° or greater, based on heat sink fins, diode direction and general construction. Two identical lights—one directional (i.e. LED) and the other with global output (i.e. CFL)—can have the same luminous flux, but depending on the location in relation to the bulb, will have very different candle and illuminance power.

| Incandescent light | Luminous flux |
|---|---|
| 40 w | 450 lumens |
| 60 w | 750–900 lumens |
| 75 w | 1100–1300 lumens |
| 100 w | 1600–1800 lumens |

### *Use of LED Lights for Poultry*

LED lights are becoming more common for use with poultry around the world because they are energy-efficient, full-spectrum and long-lasting.

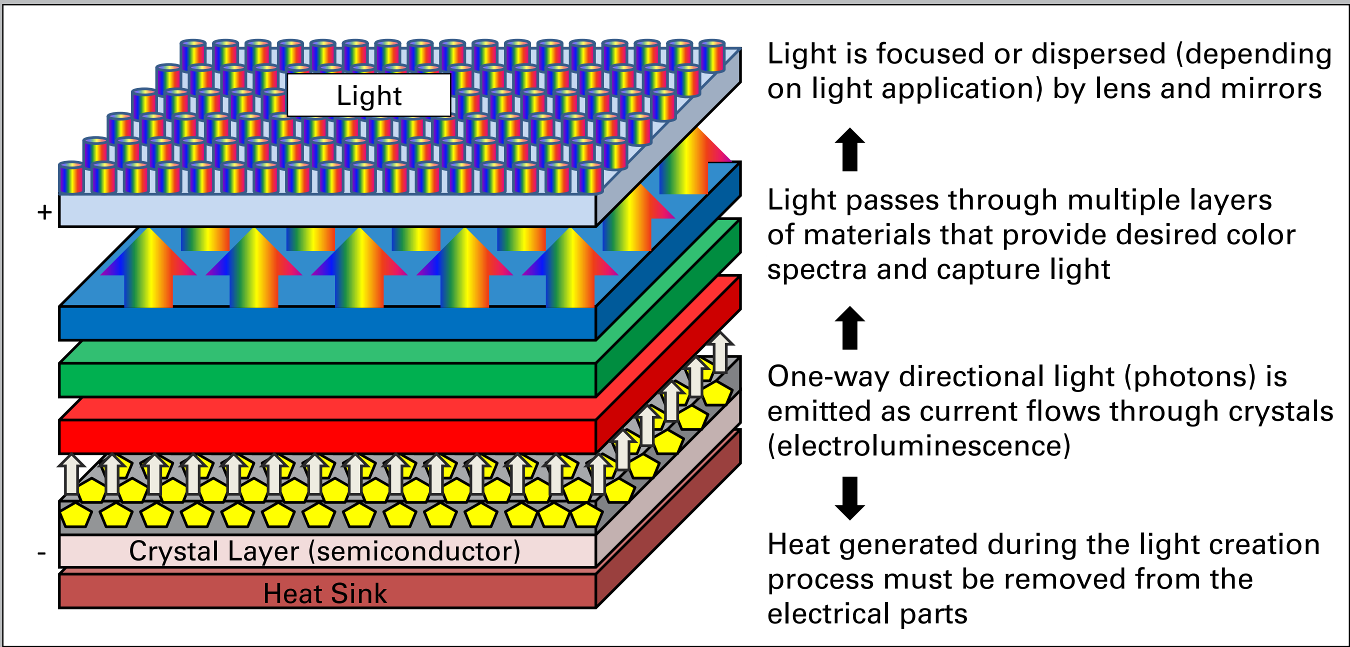


*Figure 17. How LED light is created.*

### *The Importance of Lens Diffusion*

The light emitted from an LED bulb is inherently directional, and may create shadows when there is poor lens diffusion or placement in the poultry house. While achieving a light angle output of less than 180° can be beneficial in directing light toward the birds, the spacing of the lights must be appropriate to avoid shadows. Lights hung too low or with a beam angle of less than 120° produce the effect of "spotlighting," where cones of light and dark areas are created in the house. While these lights can be utilized effectively, spotlighting can be minimized by careful placement and spacing of the lights. Uneven light distribution is an issue in both floor and cage housing systems. In floor houses, uneven lighting causes shadows, creating nesting areas for birds and resulting in higher levels of floor eggs. In cage or colony houses, uneven light distribution may cause some cages to have too much or too little light, leading to both over and under stimulation in the same house.

LED lights do not emit as much heat as incandescent or fluorescent lights; therefore, plastic or polycarbonate materials can be utilized for the lens and diffuser. While the newer generation LED lights have better light diffusion, it is still important to understand the directional light output of LED bulbs when planning your lighting system, taking into account the placement, light intensity and intended usage. Most LED manufacturers have computer programs to assess the distance, height and lumen output required to adequately light any facility.

*Figure 18. The LED lights installed in this house are too directional, too far apart and not bright enough. The combination of these factors leads to the obvious shadows on the floor and poor light uniformity along the cages.*

### *Understanding Lumens and Directionality for Different Poultry Systems*

In colony cages, select a directional light that illuminates the scratch pad and feed/water lines, while leaving the nest in shadow. When LED lights are hung in the aisle outside cages, an appropriate directional light will provide uniform light intensity to all tiers of cages, as shown in Figure 19.

The lumen output of a light does not account for the peak wavelength spectrum. For example, two LED lights that are both listed at 800 lumens may elicit different responses from chickens if the color spectra of the lights are different. While using chromaticity (K) can help separate different lights with similar luminosity, this measurement does not accurately account for the full spectral quality of the light.

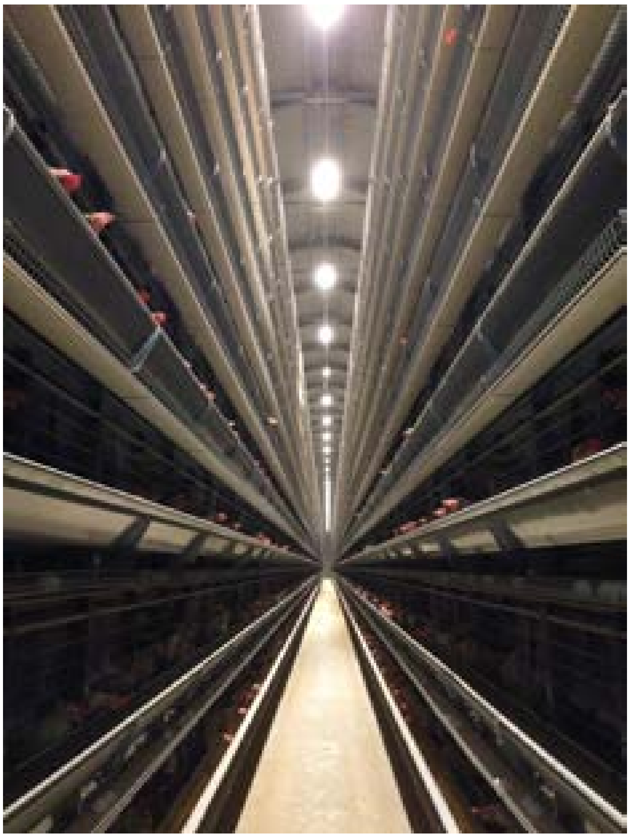

*Figure 19. Even lighting for all tiers of cages.*

## ELECTRICAL REQUIREMENTS FOR LED LIGHTS

### *Wiring*

LED lights may require different electrical wiring in a house. Some states and countries ban the use of screw-type sockets that are not water-tight and instead require that lights be wired directly into junction boxes. Check local regulations before installing or retrofitting a house for LED lights.

### *Dimming LED Lights*

Dimmers need to be compatible with the specific LED lights installed and used with an LED bulb that is rated for dimming. Incompatible dimmers may cause LED lights to flicker, overheat or burn out more quickly. LED lights do not have a resistive filament like an incandescent bulb, and require dimmers to be able to handle the complex electrical load to control wattage output. Not all LED lights are designed to be dimmable, and not all dimmable LED lights will work exactly as intended.

A good dimmable LED light requires the right equipment to dim even with a proper LED dimmer. A good LED dimmer will have resistance built into the dimmer to ensure consistent performance when dimmed. LED lights maintain efficiency when dimmed, and may increase the bulb life.

Work with the LED manufacturer to ensure you have the correct dimmer installed. Incandescent and LED dimmers both operate similarly; however, LED dimmers must have greater control of wattage output. If a dimmer turned to 50% is fluctuating + / - 3 watts, a 60-watt incandescent bulb will jump in power usage from 27 to 33 watts, which may not be perceptible to the human eye. The same dimmer fluctuating for a 10-watt LED bulb will cause the difference in power usage to jump between 2 and 8 watts. This extreme change in power going into the light will cause noticeable flickering. Additionally, even small fluctuations in power will cause dimmed LED lights to flicker.

### *Choosing the Best LED Bulb for Your Chicken House*

Selecting the right LED light bulb can be difficult once the decision to retrofit or build has been made. There are three classes of LED bulbs currently available:

1. **Poultry-specific LED lights**—Although the most expensive, poultry-specific LED lights are engineered for poultry vision, and their manufacturers understand the needs of the poultry industry. These lights are typically rated to withstand cleaning and disinfection procedures in a chicken house.
2. **General LED lights rated for agricultural use**—General agriculture-grade LED lights usually withstand the environmental conditions of a poultry house. While these lights are less expensive, understanding their full details (including light output, spectrum, warranty and level of waterproofness) is important before installation.
3. **Standard household LED lights**—Standard household LED lights have also been used in poultry houses with many of the same issues as the agricultural LED lights. These lights are typically not rated for use at 16 hours per day, leading to higher levels of premature dimming or burn out due to inadequate heat sinks or circuitry.

Overall, different types of LED bulbs have different ideal uses. Very directional lights (30–50°) placed closely together on 6–8-foot centers (1.8–2.4 m) can provide even lighting in tall caged houses. Very broad lights (>180°) are more effective for floor and aviary houses. Lights with medium directionality (90–150°) can be used in a variety of environments, depending on the spacing and the luminous flux.

## CONCLUSION

Light duration, spectrum and intensity are critical for optimum peaks and sustained egg production. While there are many choices in lighting available to the poultry producer, LED lights are becoming increasingly popular due to the combination of energy efficiency, reliability and long bulb life. As the use of LED lights increases, the understanding of proper application in various housing types will increase. Lower product costs and improved efficiency and application of LED lights can be expected in the future.

## DISCLAIMER

This technical bulletin is only intended to educate producers on various lights and lighting resources. Any changes to electrical systems on a farm should meet local regulations.

## REFERENCES


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## IMAGE SOURCES

Figure 1. Adapted from Prescott and Wathes, 1999

Figure 2. Adapted from Schubert, 2006

Figure 3. Hy-Line International

Figure 4. Encyclopaedia Brittanica, Inc. 2007

Figure 5. www.mediacollege.com

Figure 6. "CIE 1960 UCS" by Adoniscik - Own work. Licensed under Public Domain via Wikimedia Commons - http://commons.wikimedia.org

Figures 7–19. Hy-Line International